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American Institute of Electrical Engineers

COMING MEETINGS

Midwinter Convention, New York, February 9-12

Spring Convention, St. Louis, April 13-17

Annual Convention, Saratoga Springs, June 22-26

Pacific Coast Convention

Regional Convention, District No. 2, Washington, D. C., January 23-24, Cleveland, May 22-23

Regional Convention, District No. 1, Swampscott, Mass., May

MEETINGS OF OTHER SOCIETIES

American Engineering Council—Washington, D. C., Jan. 16

American Society of Civil Engineers, New York, Jan. 21-23

Engineering Institute of Canada, Montreal, Jan. 27-29

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OF THE

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Current Electrical Articles Published by Other Societies

ALTERNATING CURRENT UNDERGROUND DISTRIBUTION IN NEW ORLEANS.

By W. R. Bullard. *Proc. Louisiana Engng. Soc.*, Aug. 1924, vol. 10, pp. 179-99. 21 pp.

SUPER-HETERODYNE—ITS ORIGIN, DEVELOPMENT AND SOME RECENT IMPROVEMENTS.

By E. H. Armstrong. *Proc. Inst. Radio Engrs.*, Oct. 1924, vol. 12, pp. 539-52. 2600 w.

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By R. W. Newcomb. *Proc. Engr. Soc.* West Penn., Oct. 1924, vol. 40, pp. 249-80. 32 pp.

ELECTRIC DOMESTIC REFRIGERATION.

A report of the electric domestic refrigeration committee of the Appliance Bureau. Commercial National Section.

Natl. Elect. Light Assoc. N. Y., May 20, 1924. Publication No. 24-22C. 11 pp.

APPLICATION OF ELECTRIC ENERGY TO THE MODERN ICE MAKING AND REFRIGERATING PLANT.

By P. Schlingman. *Refrig. Engng.*, Nov. 1924, vol. 11, pp. 165-72. 6000 w.

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By A. E. Kennelly. *Proc. Amer. Philosophical Soc.*, 1924, vol. 63, pp. 171-89. 19 pp.

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By C. J. de Groot. *Proc.* Inst. Radio Engrs., Dec. 1924, 12. 693-722. 30 pp.

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By A. J. Sorensen. *Physical Rev.*, Dec. 1924, 24. 658-65. 1300 w.

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By H. D. Smyth. *Jnl.* Franklin Inst., Dec. 1924, 198. 795-811. 17 pp.

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By J. B. Brady. *Proc.* Inst. Radio Engrs., Dec. 1924, 12. 849-64. 15 pp.

THEORY AND EXPERIMENTS RELATING TO THE STRIATED GLOW DISCHARGE IN MERCURY VAPOR.

By K. T. Compton and others. *Physical Rev.*, Dec. 1924, 24. 597-615. 19 pp.

INTERNATIONAL COMPARISON OF RADIO WAVE-LENGTHS STANDARDS BY MEANS OF PEIZO-ELECTRIC RESONATORS.

By W. G. Cady. *Proc.* Inst. Radio Engrs., Dec. 1924, 12. 805-21. 17 pp.

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By S. Ballantine. *Proc.* Inst. Radio Engrs., Dec. 1924, 12. 823-32. 2100 w.

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By F. Davis. *Jnl.* Amer. Weld. Soc., Nov. 1924, 3. 1820. 500 w.

Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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Institute Activity as Seen by the President

Never before in the history of the Institute has there been such universal activity on the part of its members through the respective sections and districts all over the country.

On the President's recent trip in the Far West, during which meetings were held in Pasadena, Los Angeles, San Francisco, Portland, Seattle, Vancouver, Spokane, as well as at the California Institute of Technology and Leland Stanford University, splendid enthusiasm was evident, both on the part of the individual member and groups. Although there was not time to arrange for section meetings, there were group meetings of our members at Panama and Havana carrying no less enthusiasm with them than the meetings formally scheduled as Section gatherings.

The activity of the members indicates the realization that the Institute, while it is of course national, and in fact international, in its membership, has a practical work to do, of interest to all and one in which all may participate.

The geographical distribution of assignments as indicated by the different members of committees has accomplished a feeling of intimacy and confidence which has knit together in family spirit the workers of our Institute most efficiently and satisfactorily.

The large percentage of members in attendance at all meetings shows fine interest, and the District Meetings are bringing groups together more often than was formerly possible. The visiting of the Vice-Presidents to the various sections of the districts is causing a feeling of closer relationship, and bringing about a more ready exchange of ideas for the good of the Institute than has been possible heretofore.

The large group of representative men who went from the East to the Pasadena Convention was a direct means of an exchange of thoughts among members of the Institute from opposite sides of the country, not only to revive many pleasant friendships, but, through discussion, bring to the front, information of value to our Institute.

The co-operation of members with the other Founder Societies is everywhere evidenced through joint meetings, thus cementing together the units of all branches of engineering, an act so essential to the carrying on of indisputable inter-dependence in our great engineering works.

That the whole engineering group as a committee can formulate a useful opinion in its line, is without question, and the very best method of developing confidence and respect for such opinions is by joint meetings of engineers of all kinds, many times with the general public invited to such meetings that they may learn what a really useful body of men an engineering group can be.

With all the technical activities necessitated by the rapid advance of our art and the immediately practical applications of such advances, let us not forget that we should not only be engineers for engineering, but we should have no less an understanding and responsibility as engineers for humanity.—*Farley Osgood.*

M and P Committee Preparing Guides for Committee Work

The Meetings and Papers Committee of the Institute is endeavoring to set up as definitely as practicable codes or guides for the work of the Committee and that of Technical Committees insofar as it has jurisdiction. It is hoped that permanent working guides can be established which may be handed down from year to year. These should be of much value to new committees which are appointed in the future as well as of use to the present committees.

Along this line the Committee prepared during last year the first draft of a code for general activities of the Committee, for the acceptance of papers, for the conduct of technical sessions and for the conduct of Institute Conventions. This code has undergone considerable revision already and before it is finally adopted other changes will be made.

Related to this code is the booklet "Hints to Authors" which is available to any Institute member and which offers numerous suggestions to aid in the preparation of papers and outlines the accepted practise with regard to preparing and handling manuscripts. This booklet has recently been brought up-to-date by this Committee and the Publication Committee.

The activities of Technical Committees is another subject which has been discussed with the thought of preparing a permanent guide. At a meeting of the Committee on December 19 the combined suggestions of several Technical Committee Chairmen were studied and it is thought that after further discussion a permanent guide will ultimately be formulated. This guide would give details of the activities of the Technical

Committees and suggest the possible organization for handling the work. It would cover such activities as standardization, technical papers, annual reports, research, news items for the JOURNAL and cooperative work with other organizations. It would supplement the report made during 1924 by the Committee to Review Technical Activities of the Institute which covered the activities in a broader way. Of course the portions of the guide relating to work done under direction of other committees, such as the Standards Committee, would be outlined by those committees before the guide could be adopted.

It is hoped that within the present year these guides can be developed and put into such form that they may be printed and kept for the use of present and future committees.—*Meetings and Papers Committee.*

The New York-Azores Submarine Cables

On September the 21st, there was placed in operation the first inductively loaded submarine telegraph cable ever laid. This cable, which is owned by the Western Union Telegraph Company, stretches from New York to the Azores forming part of what will eventually be the first direct cable between the United States and Italy.

For various reasons, it is not found practicable to apply to submarine cables the coil type of loading which is employed on land lines. In the present cable the increased inductance is obtained by winding spirally around the copper conductor of the cable a tape of the new nickel-iron alloy "permalloy," forming a layer 0.006 in. thick. In other respects the cable resembles very closely the ordinary type of submarine cable.

The object of loading a telegraph cable is to raise the "signal frequency," which determines the rate at which messages can be transmitted over the cable. The degree of success attained in the present case can be judged from the fact that legible signals have been transmitted over the cable at a speed of more than 1900 letters per minute, which is more than six times the speed of transmission over a non-loaded cable of the same size.

The new cable represents the result of several years research work in the laboratories of the Western Electric Company, in the course of which the loading material, permalloy, having a permeability many times that of ordinary iron, was discovered. The cable was designed by the Western Electric Company which also supervised its actual manufacture at the works of the Telegraph Construction & Maintenance Company in London.

In order to test and operate this cable which has electrical characteristics so markedly different from those of the usual type of submarine cable it has been necessary for the Western Electric Company to develop special types of measuring and signaling apparatus, including a vacuum tube amplifier at each terminal for "shaping" the incoming signals.

An interesting feature of the new cable is its freedom from local electrical disturbances, a serious handicap to all cables extending easterly from the Atlantic Coast of the United States. On account of the comparative shallowness of the water in which the terminal sections lie, they are sensitive to disturbances due to the atmosphere and to electric power systems. In order to avoid this difficulty with the new cable, its ground connection was placed at a distance of about 100 miles from New York. This precaution appears to have entirely eliminated the effects of outside electrical disturbances.—*Committee on Communication.*

Abstracts of Papers in the Journal

The crowded conditions of the Institute's publications during 1924, which has been commented upon at various times during the year, reached a crisis at the close of the year offering only two alternatives to the Publications Committee: One, to abstract drastically all the remaining papers and complete the year's production in the December JOURNAL, thus starting the present year with a clean slate; and the other, continue the publication of last year's papers in this year's JOURNALS, thus indefinitely extending the publication congestion.

It was with genuine regret that the former alternative ultimately had to be decided upon, resulting in the publication of some twenty-five papers in such brief abstract as was necessary to accommodate them to the limits of a single issue of the JOURNAL. It is apparent, of course, that these abstracts were totally inadequate representations of the papers—many of which rank among the most important of the year,—but as no discrimination was possible, all of the papers remaining unpublished were similarly treated. The situation is greatly relieved, however, by the fact that any of these papers in complete form is available to readers on application.

It is to be hoped that the Meetings and Papers Committee will be able to restrict this year's programs to an amount that can be included in the JOURNAL; and this situation also should suggest to authors the necessity of the greatest possible condensation in the preparation of papers, as about eight pages is the limit of printed space that is available per paper. Anything longer will require abridgment.

Dielectric Properties of Fibrous Insulation
As Affected by Repeated Voltage Application

BY F. M. CLARK[1]
Associate, A. I. E. E.

Synopsis.—*It is believed by many that the most plausible explanation of fibrous insulation failure is the pyro-electric theory. Under this theory as elaborated by Steinmetz, Wagner and others, insulation under stress is heated by the transformation of electric energy to thermal energy. Insulations are considered as of the nature of poor conductors and subject to the same characteristics. The transformation of electric to thermal emergy is therefore dependent upon the inherent electrical and thermal conducting properties of the material. This transformation proceeds at a rate proportional to the stress applied, until such a voltage value is reached where the heat is generated in the insulation at a rate faster than it is dissipated to the surrounding medium. Further increase in voltage leads to a rapidly mounting temperature with ultimate insulation failure. A strict interpretation of this theory would indicate that insulation failure is a matter of the insulation resistance—temperature relation. Therefore, as the heat stored in a dielectric during stress is allowed to dissipate, care being taken to prevent injury from the testing electrodes, etc., the orignial properties of the material should be restored. This has been found to be true only to a limited extent.*

The present paper deals largely with the effect of relatively high-voltage applications on sheet insulation tested between parallel plate electrodes. It is shown that the question of the mechanism of insulation failure can be separated into two parts. First, failure caused by short-time voltage applications as determined by rapidly applied tests, and secondly, failure of insulation under longer periods of stress as determined by the minute or endurance test methods.

Peek has found that voltages greatly in excess of the "rapidly applied" 60-cycle puncture voltage may be applied to the insulation without rupture, if the time of application be sufficiently short. All such over voltages injure the insulation, "probably by a mechanical tearing and the effect is cumulative." In these experiments of short duration, the problem of heat storage in the insulation is eliminated.

Raynor has found that the rapidly applied strength of insulation is greatly lowered by the previous application of a high voltage. This decrease in strength, however, is lost, given sufficient rest period between the initial and final voltage application. These results are substantiated in the work of the present paper. The length of rest period is shown to be proportional to the initial test voltage applied.

For tests of long duration, the work of this paper has been divided into two parts,—those voltages producing failure with an arbitarry time limit (15 minutes) and those voltages which are able to be applied for an indefinite time without a puncture. According to the pyro-electric theory, the first class deals with those voltages of such value as to produce a slowly mounting temperature rise in the insulation which ultimately reaches a value leading to rapidly decreasing insulation resistance and total loss of dielectric strength. The second class includes those voltages of such value that the rate of transformation of electric to thermal energy is equaled by the rate of dissipation of the heat so formed; thus preventing heat storage in the insulation. According to the thermal theory of breakdown, neither of these voltages should produce permanent injury to the dielectric,—the first, if removed before the stage indicating rapid loss of insulation resistance is reached, and the second, even if applied indefinitely. The present paper shows that the application of voltages of either of the above types leads to deterioration in dielectric strength of fibrous insulation, even aside from such effects that might be traced to corona or mechanical injury to the material. The effect for voltages of the first class is cumulative and expressed by the formula $R \times T = K$ where R = number of repetitions of voltages, T the time of each voltage application, and K the time needed to puncture for the same voltage continuously applied. The application of this formula to various insulations, its limitations, etc., are discussed.

The work detailed herein concerns the application of a-c. voltages at room temperature. The investigation is being extended to cover both low and high a-c. and d-c. voltages at and above room temperatures.

Object

It has generally been assumed that when a fibrous insulation is subjected to a potential stress, unless the critical point is reached and exceeded (that is, the point where the resistance suddenly decreases thus allowing the current to run away), the structure of the insulation although temporarily weakened dielectrically, is not permanently damaged and will recover if given a sufficient rest period. Some tests made in a preliminary way indicated that the above assumption was not correct. An extended study of the effect of repeated application of voltage on the dielectric strength of fibrous insulations has proven the validity of these preliminary experiments.

Up to the present time the tests have been confined to 60-cycle voltages and with the materials at room temperatures. Further work is being carried on in this field of research covering the effect of intermittently applied stress under various conditions using d-c. as well as a-c. voltages.

Conclusions and Results

The work done under the above stated conditions shows that the breakdown point is generally decreased by a previously applied voltage, this effect being greater as the actual point of failure is approached during the previous test. The exception to the case occurs with rapidly applied tests after a rest period following a previous voltage application. In this instance the material breaks down at approximately the same value with or without the previous application of stress.

However, the intermittent application of a voltage of such a value as will cause breakdown within 15 minutes, if continuously applied, results in a progressive weakening in the strength of unvarnished oil treated fibrous material, the effect being roughly additive.

With the application of a very low voltage producing

1. Physicist, General Electric Company, Pittsfield, Mass.

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 9-12, 1925.

no puncture for indefinite time, a deterioration in the strength of oil treated paper has been observed. This in part, however, is able to be traced to a change accompanying oil immersion over long periods.

For varnished insulation, the repeated application of voltage leads to increased long time strength, probably due to a further drying out process taking place under the influence of the applied stress.

With mica or with fibrous materials heated in oil between voltage applications, the effect of intermittently applied stress is diminished and an increase in dielectric life is observed.

For low-voltage application, no permanent change in percentage power factor determination for oil treated fibrous materials has been noted. With high voltages, the per cent power factor values are extremely erratic, but in general show an increase up to the point of failure.

Discussion

It has been shown in an unpublished paper[1] that the strength-thickness relation characteristic of fibrous insulation is greatly affected by voltage application even at low stresses. Thus for example, the relation expressed in the formula $KV = A\,T^{0.72}$ as determined for oil impregnated 0.0005-in. linen paper from 0.002-in. to 0.008-in. in thickness is changed to $KV = A\,T^{0.56}$ for a ten-day application of 3300 volts. At the end of 51 days the relation has become $KV = A\,T^{0.52}$ which is practically unchanged at the end of 77 days of voltage application.

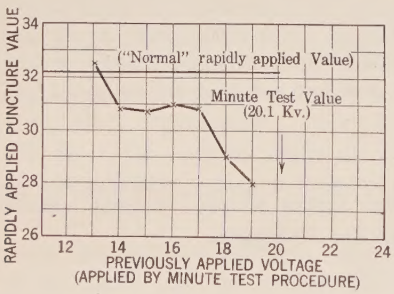

Fig. 1—Effects of Previously Applied Voltages on the Rapidly Applied Puncture Value of Three Layers Black Varnished Bond Paper (0.005 In.)

Test Medium—Transil Oil at Room Temperature
Electrodes—1½-in. Brass with Edges Rounded to 3/64-in. Radius
Test Voltage—60-cycle

Continued study has been made of the effect of voltage upon the breakdown values of a variety of fibrous insulating materials. Experimental data has shown that the important factors involved are the voltage itself, the rest period allowed between applications of stress, the duration of voltage application, and the treatment of the insulation during the rest interval between stress periods.

1. Dielectric strength-thickness relation in fibrous insulation by F. M. Clark and V. M. Montsiiger.

The Voltage Factor with Reference to the Rapidly Applied Test Values

It has been found that the rapidly applied breakdown value for black varnished bond paper tested under oil at room temperature is affected by the previous application of electric stress, the effect being greater the nearer the applied voltage is brought to the actual breakdown strength of the insulation. This is illustrated in the following data, all values of which are the average of at least ten tests, the individual tests for the different points being run alternately on the same samples of insulation.

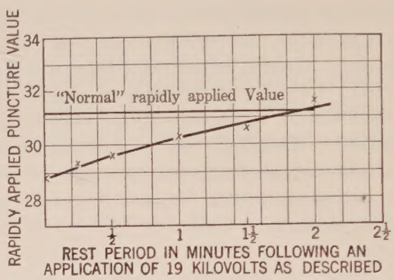

Fig. 2—Effect of a Previously Applied Voltage on the Rapidly Applied Puncture Value of Three Layers of Black Varnished Bond Paper (0.005 In.) as a Function of the Rest Period Involved

Test Voltage—60-cycle
Test Medium—Transil Oil at Room Temperature
Electrodes—1½-in. Brass with Edges Rounded to 3/64-in. Radius

Insulation—3 layers black varnished bond paper (0.005 in.)

Testing voltage—60 cycles.

Testing medium—transil oil at room temperature.

Electrodes—1½ in. brass, with edges rounded to 3/64 in. radius.

Voltage Applied	Breakdown
Rapidly applied (original)	32.2 kv.
Minute test (initial voltage 12 kv. with 1 kv. stepup each 30 seconds) (Original)	20.1 kv.
Rapidly applied preceded by voltage application according to the above minute test procedure up to and including 19 kv.	28 kv.
Rapidly applied preceded as above by the minute test voltage application up to and including 18 kv.	29 kv.
Rapidly applied preceded as above by the minute test voltage application up to and including 17 kv.	30.8 kv.
Rapidly applied preceded as above by the minute test voltage application up to and including 16 kv.	31.0 kv.
Rapidly applied preceded by voltage application by the minute test procedure up to and including 15 kv.	30.7 kv.
Rapidly applied preceded by voltage application by the minute test procedure up to and including 14 kv.	30.8 kv.
Rapidly applied preceded by voltage application by the minute test procedure up to and including 13 kv.	32.5 kv.

These results are illustrated in Fig. 1. Similar effects have been noted using 3-mil. oil-impregnated kraft paper.

The Effect of Rest Period Between Voltage Applications

The extent of the deterioration in the rapidly applied test strength of fibrous insulation is dependent upon the rest period allowed between applications of stress.

Insulation—3 layers black varnished bond paper (0.005 in.)

Test medium—transil oil at room temperature.

Electrodes—1½ in. brass electrodes, edges rounded to a radius of 3/32 in.

Averages based on ten tests. The individual tests for each point were run alternately upon the same samples of insulation.

CASE I (FIG. 2)

Original rapidly applied strength.....................31.2 kv.
Minute test strength (Initial voltage 12 kv. followed by 1 kv. increments each 30 seconds)..(original)..20 kv.

Preliminary treatment—voltage applied according to the above minute test procedure up to and including 19 kv.

Rest Period	Final Rapidly Applied Strength
No rest	28.8 kv.
¼-min. rest	29.3 "
½-min. rest	29.6 "
1-min. rest	30.3 "
1½-min. rest	30.6 "
2-min. rest	31.6 "
3-min. rest	31.8 "

Similar results have been obtained using 0.003 in. oil impregnated kraft paper.

CASE II (FIG. 3)

Original rapidly applied strength.....................30.7 kv.
Minute test strength (initial voltage 12 kv. followed by one kv. stepup each 30 seconds)....(original)......20 kv.

Preliminary treatment—voltage applied according to the above minute test procedure up to and including 17 kv.

Rest Period	Final Rapidly Applied Strength
No rest	29.5 kv.
¼-min.	29.8 "
½-min.	30.2 "
1-min.	30.5 "
1½-min.	30.6 "
2-min.	30.5 "
3-min.	30.8 "

Similar results have been obtained using 0.003 in. oil impregnated kraft paper.

Effect of Previously Applied Electric Stress Upon the Time-Voltage Relation

The effect of stress application upon the time-voltage relation in fibrous insulation is of interest since it not only involves tests of short duration but also long time tests. In this work the time factor involved has been limited to 15-minute intervals.

In investigating this phase of voltage effect, the stress applications fall into two classes,—first those voltages which will puncture the insulation within an arbitrary time (15 min.) and secondly, those voltages which will give no puncture independent of the time for which applied.

Case I: Those voltages producing a puncture within 15 minutes. The effect of voltages of this type has been investigated with the use of oil impregnated 0.003 in. kraft paper and 0.005 in. black varnished bond paper. The results are shown in Figs. 4 and 5. In these figures the points shown are the average values of at least ten tests. The individual tests upon which the averages of the curves are based have been obtained alternately.

The following facts in Fig. 4 are to be noted:

First, the rapidly applied test value of oil treated kraft paper is greatly affected by the previous voltage application, which effect is partly eliminated with the the intervention of a rest period between the preliminary voltage application and the final test value;

Secondly, the application of stress leads to a permanent injury as determined by the long time test value. That is, the curves with and without a rest period following the initial stress application become identical when the time to puncture factor equals one minute or more.

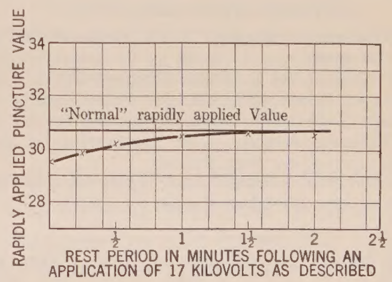

Fig. 3—Effect of a Previously Applied Voltage on the Rapidly Applied Puncture Value of Three Layers of Black Varnished Bond Paper (0.005 In.) as a Function of the Rest Period Involved

Test Voltage—60-cycle
Test Medium—Transil Oil at Room Temperature
Electrodes—1½-in. Brass with Edges Rounded to 3/64-in. Radius

In Fig. 5 for the varnished paper, although similar effects are noted for short time tests, as observed in Fig. 4 for kraft paper, nevertheless considerable difference is observed in voltage strength for tests occupying more than one minute, where an apparent increase in dielectric strength is obtained following the intervention of a rest period between the initial and final voltage applications. In view of the fact that it is impossible to thoroughly dry varnished materials without injury before test, the increase in strength always noted with low voltage applications has been attributed to a further drying out process.

Case II: Those voltages which do not puncture at indefinite time. The effects of very low stress application involving as it does a period of weeks and months has necessitated the use of a slightly different test method. In this procedure aluminum foil electrodes (1½ in. by 2½ in.) were prepared between which was clamped the insulation under test. The dielectric used was linen paper, 0.0005 in. per layer and made up to a thickness of 0.004 in. The individual units so prepared were carefully dried under vacuum at 115 deg. cent. and impregnated. Part were then tested for the

time voltage relation. The remainder were then submitted to 3300 volts in oil at room temperature. No attempt was made to protect the oil in which the units

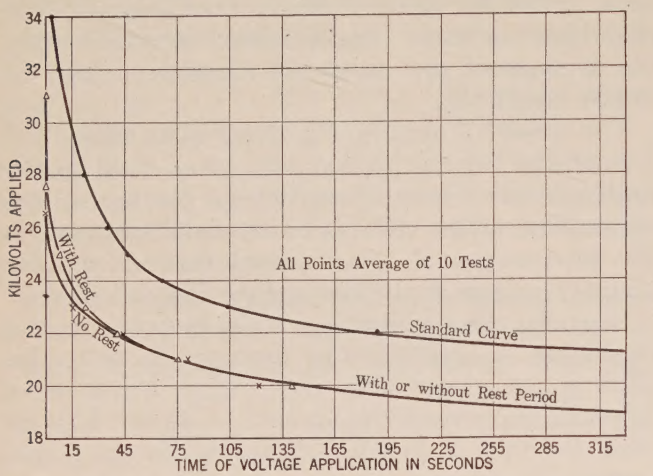

Fig. 4—Effect of a Previously Applied Voltage on the Time-Voltage Relation

Insulation—9 Layers Oil Treated Kraft Paper (0.003 in.)
Test Voltage—60-cycle
Test Medium—Transil Oil at Room Temperature
Electrodes—1½-in. Brass with 3/64-in. Edge Radius
"Standard Curve"—Original Curve for Insulation
"No Rest"—Relation obtained after Application of 22 kv. for 2½ min. without an Intervening Rest Period
"With Rest"—Relation obtained after Application of 22 kv. for 2½ min. followed by a Rest Period of 5 min.

were placed from the effects of the room conditions, aside from the fact that the tests were made in a large "voltage box," covered but not air-tight. The results are shown in Fig. 6. Here again it will be noted that

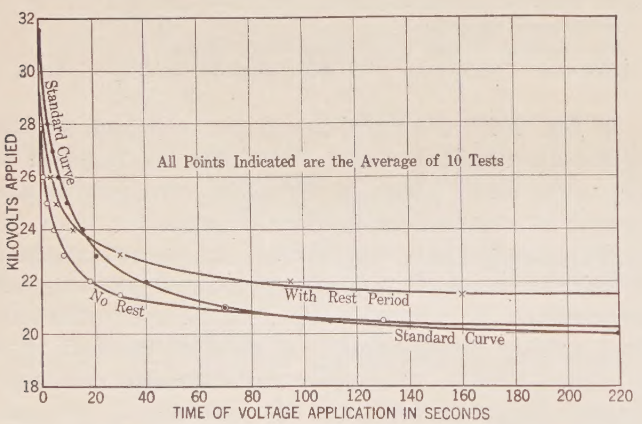

Fig. 5—Effect of a Previously Applied Voltage on the Time-Voltage Relation

Insulation—Two Layers Blank Varnished Paper (0.012 in.)
Test Voltage—60-cycle
Test Medium—Transil Oil at Room Temperature
Electrodes—1½-in. Brass Edges Rounded at 3/64-in. Radius
"Standard Curve"—Original Curve for Insulation
"No Rest"—Relation obtained after Application of 20 kv. for 150 sec. without an Intervening Rest Period
"With Rest Period"—Relation obtained after Application of 20 kv. for 150 sec. followed by a Rest Period of 5 min.

permanent deterioration has occurred in the insulation except in the case of rapidly applied test values.

The effect of long time voltage application at low stress has been investigated by means of the effect noted upon the one minute test values of 0.0005 in. linen paper in thicknesses from 0.002 in. to 0.008 in. In this connection, units similar to those described above were carefully dried under vacuum and oil impregnated. Part were tested by minute test procedure and the remainder placed under 3300 volts in oil at room temperature for varying periods, after which the minute test values were again determined. The results are shown in Fig. 7. It should be remembered that in this case the units tested being of varying thicknesses, the actual electric stress (volts per mil) was not constant. It is to be noted, however, that the minute test value for the 4-mil thickness is affected in almost equal amount in Fig. 6 and Fig. 7, in both of which cases the voltage has been applied for equal intervals, 77 days.

During the course of these experiments, no attempt

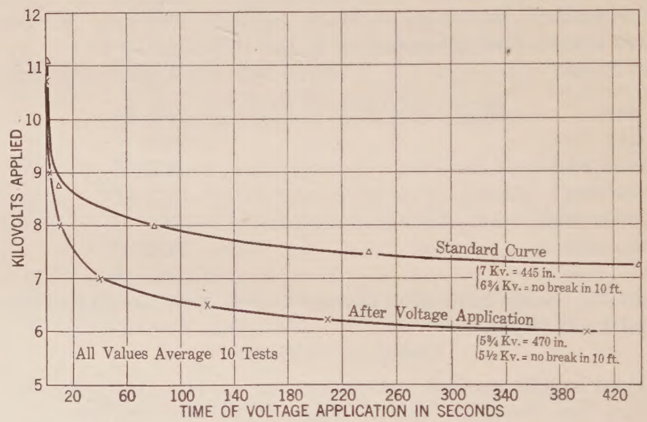

Fig. 6—Effect of a Previously Applied Voltage on the Time-Voltage Relation

Insulation—8 Layers of Oil-Treated Linen Paper (0.0005 in.)
Test Voltage—60-cycle
Test Medium—Transil Oil at Room Temperature
Electrodes—1½-in. by 2½-in. Aluminum (0.001 in.) Foil
"Standard Curve"—Original Curve for Insulation
"After-Voltage Application"—Time-Voltage Relation after the Application of 3300 Volts for 77 Days

has been made to protect the insulation from the effects traceable to atmospheric conditions, the samples being merely immersed under oil whose surface was in contact with the air, of the "voltage box." Fig. 7 also shows the effects which are traceable to factors aside from the applied voltage.

It will be noted in Fig. 4 that the total time to produce a puncture with oil impregnated kraft paper at 22 kv. was originally 188 seconds. In the case when 22 kv. was applied for 2.5 minutes followed by a rest period of 5 minutes, the insulation punctured on the second application of voltage in 42 seconds, the total time for which the 22 kv. was applied before and after the rest period being 192 seconds. Thus the breaking-up of the voltage application into two steps separated by a rest period produced no material increase in the original voltage life of the insulation. A permanent injury of an additional type was apparently produced by each application of voltage.

Repeated Applications of Voltage Stress

In investigating the effects of repeated applications of electric stress, the voltages used were in general limited to those producing a puncture within a time interval of 15 minutes. In order to express the results of the various individual experiments in an easily comparable manner, the following scheme was used. A definite voltage was selected which would produce a puncture continuously applied within the time interval desired. Using this voltage, the average time to puncture on at least 10 tests was determined. This time was accepted as the 100 per cent time factor, *i. e.*, the total time needed to produce a puncture for only one application of the voltage used. With this factor as a basis, the constant voltage accepted was applied for various intervals such as 90 per cent, 80 per cent, 70 per cent, etc., of the 100 per cent time value. With a period of rest allowed between voltage applications, the number of permissible repetitions of stress for each time interval was determined.

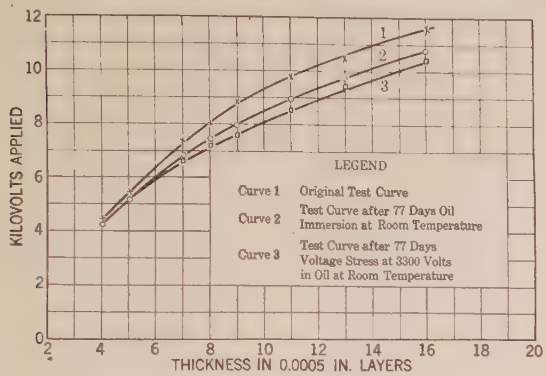

Fig. 7—The Effect of Low-Voltage Stresses upon the Minute-Test

Puncture Value of Fibrous Insulation
Insulation Used—Linen Paper, 0.0005 in. per Layer (2 in. by 3 in.)
Electrodes—1 mil Aluminum (1½ in. by 2½ in.) held in Place by Means of Glass Plates and Spring Clamps
Test Medium—Transil Oil at Room Temperature
Test Voltage—60-cycle
All Values Average of 8 Tests

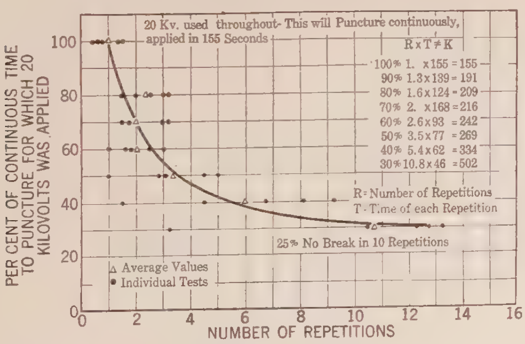

Fig. 8—Effect of Repeated High-Voltage Application upon Varnished Cambric

Insulation—Two Layers of 0.012 in. Black Varnished Cambric
Test Medium—Transil Oil at Room Temperature
Test Voltage—20-kv. 60-cycle
Electrodes—1½-in Brass with Edges Rounded to 3/64-in. Radius
Rest Period—Five min. between Tests

Case I: Figs. 8, 9, 10, 11, 12 and 13 illustrate the typical results produced by repeated voltage applications upon black varnished cambric (0.012 in.), black varnished paper (0.005 in.), kraft paper (0.003 in.), cable paper (0.005 in.), and pressboard (1/32 in. and 3/32 in.) tested under oil at room temperature. In these tests the total number of voltage applications was

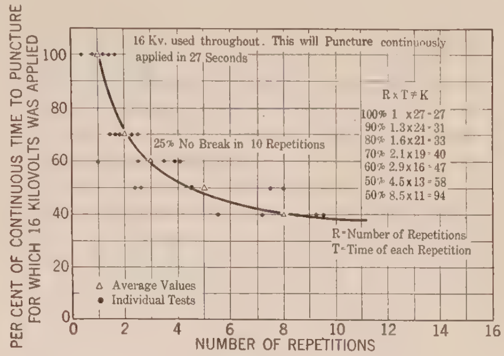

Fig. 9—Effect of Repeated High-Voltage Application upon Varnished Bond Paper

Insulation—Two Layers of 0.005 in. Black Varnished Bond Paper
Test Medium—Transil Oil at Room Temperature
Test Voltage—16-kv. 60-cycle
Electrodes—1½-in. Brass with Edges Rounded to 3/64-in. Radius
Rest Period—Five min. between Tests

limited to from 10 to 15. During the rest period, the insulation was allowed to remain in place between the electrodes immersed in cold transil oil. The varnished cambric and varnished paper were dried in air at 100 deg. cent. for four hours, after which they were immersed in transil oil for 24 hours before test. The unvarnished insulation was subjected to a vacuum drying process and oil impregnation at 110 deg. cent.

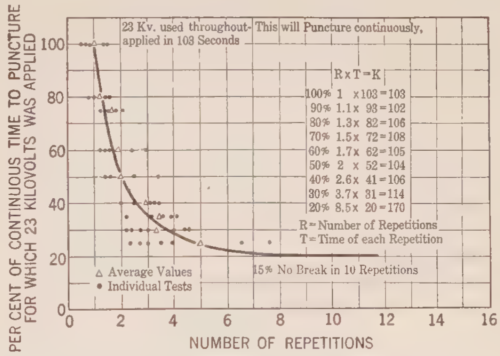

Fig. 10—Effect of Repeated Applications of High Voltage upon Kraft Paper

Insulation—9 Layers of 0.003-in. Oil-Treated Kraft Paper
Test Medium—Transil Oil at Room Temperature
Test Voltage—23-kv. 60-cycle
Electrodes—1½-in. Brass Electrodes Edges Rounded to 3/64-in. Radius
Rest Period—Five min. between Tests

It will be noted in Figs. 8 and 9 that with the varnished materials, the actual voltage life continually increases as the time of each application is diminished. This bears out the results of Fig. 5 showing the effect of previously applied stresses upon the time-voltage relation of black varnished paper. In cases where the breakdown value of varnished insulations, dried as

described, is not closely approached either with respect to the voltage or time factors, an apparent increase in voltage life results. In the case of fibrous, unvarnished but vacuum dried and oil impregnated materials, the effect of each application of voltage seems to be additional and permanent. This effect is expressed in the formula $R \times T = K$ where R is the number of repetitions possible for the time T of each application. The value of K is the time to puncture for the voltage used when continuously applied. The application of this formula is given in each of the figures showing the effect of repeated high-voltage stresses. Increased dielectric life does not result until the time factor of each voltage application has been reduced to less than 40 per cent of the continuously applied time to puncture value for the same voltage. This effect is shown in the case of kraft paper, cable paper and pressboard of Figs. 10, 11, 12 and 13.

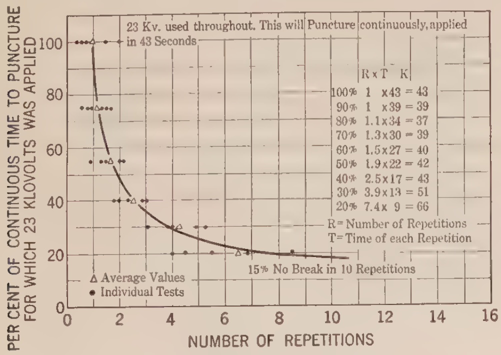

Fig. 11—Effect of Repeated Applications of 23 kv. on Cable Paper

Insulation—Six Layers of 0.0045-in. Oil-Treated Cable Paper
Test Medium—Transil Oil at Room Temperature
Test Voltage—23-kv. 60-cycle
Electrodes—1½-in. Brass with 3/64-in. Edge Radius
Rest Period—Five min. between Tests

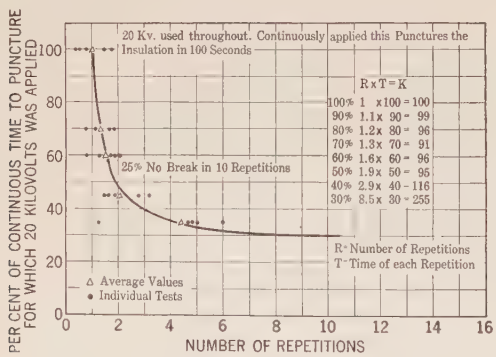

Fig. 12—Effect of Repeated High-Voltage Applications on Pressboard

Insulation—One Layer, 1/32 in. grade AA Oil Treated Pressboard
Test Medium—Transil Oil at Room Temperature
Test Voltage—20-kv. 60-cycle
Electrodes—1½-in. Brass with 3/64-in. Edge Radius
Rest Period—15 min. between Tests

Case II: In a previous article[2] it has been shown that the dielectric strength-thickness relation for fibrous insulation approaches the first power with the use of impregnated wooden electrodes. Fig. 14 shows the effect of intermittently applied voltage on 0.003 in., oil impregnated kraft paper, tested under transil oil at room temperature with 3-inch round edge impregnated wooden terminals. The effect of voltage application with these electrodes is roughly additional and in no wise different from the results illustrated in the previous figures using metallic electrodes.

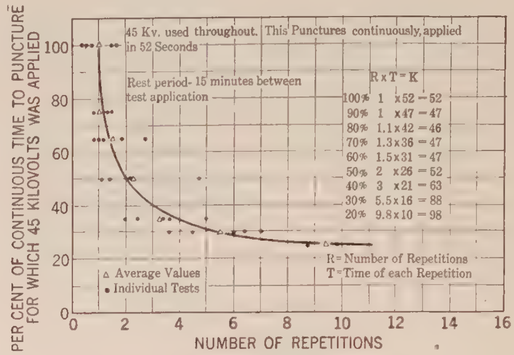

Fig. 13—Effect of Repeated Applications of High Voltage on Pressboard

Insulation—One Layer 3/32-in. Grade A Oil-Treated Pressboard
Test Medium—Transil Oil at Room Temperature
Test Voltage—45-kv. 60-cycle
Electrodes—1½-in. Brass with 3/64-in. Edge Radius
Rest Period—15 min. between Tests

Case III: In Figs. 8 to 13 inclusive 1½ in. brass electrodes with edges rounded to a radius of 3/64 of an inch have been used. It has already been shown[2] that in cases where such electrodes are replaced with terminals identical, with the exception that an albarene stone collar has closely fitted around the electrode edge forming a smooth surface with the testing face, the dielectric strength-thickness relation is changed from $Kv = A\ T^{0.70}$ to $K\ v = A\ T^{0.86}$. The effect of such "protected" electrodes on fibrous insulation under repeated applications of stress is shown in Fig. 15 for ⅛ in. pressboard in oil at room temperature. The

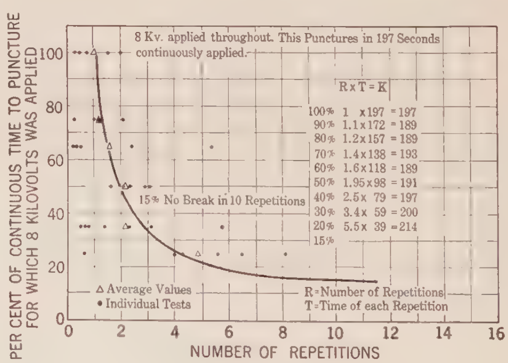

Fig. 14—Effect of Repeated Applications of Voltage on Kraft Paper

Insulation—4 Layers of Oil-Treated 0.003-in. Kraft Paper
Test Medium—Transil Oil at Room Temperature
Test Voltage—8 kv. 60-cycle
Electrodes—Three-inch, Round Edge, Impregnated Wooden Electrodes
Rest Period—20 min. between Tests

2. F. M. Clark and V. M. Montsinger—Ibid

results show a deteriorating effect additional in nature accompanying each application of voltage comparable to that illustrated in the previous figures for "unprotected" electrodes.

Case IV: In the results shown in cases I, II and III the insulation between test applications has been allowed to rest untouched in oil at room temperature.

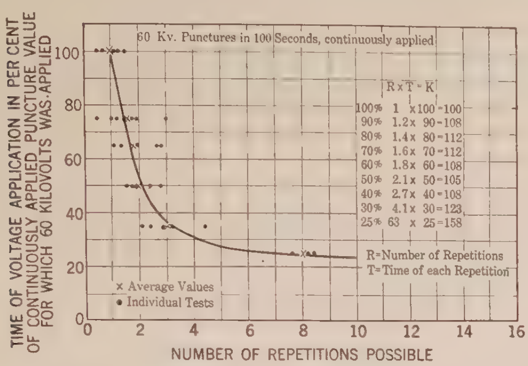

FIG. 15—EFFECT OF REPEATED HIGH-VOLTAGE APPLICATION ON PRESSBOARD

Insulation—One Layer 1/8-in. Oil-Treated Pressboard
Test Medium—Transil Oil at Room Temperature
Test Voltage—60-kv. 60-cycle, Sine Wave
Rest Period between Voltage Applications—10 min.
Electrodes—1½-in. Brass with Albarene Stone Edge Protection

Fig. 16 shows the relationship obtained, using the same procedure as in the previous cases, except that during the rest period the insulation has been heated in oil for a predetermined period. In running these tests, account had to be taken of the aging effect which would result from the intermittent hot oil immersions.

The change in dielectric strength following hot oil

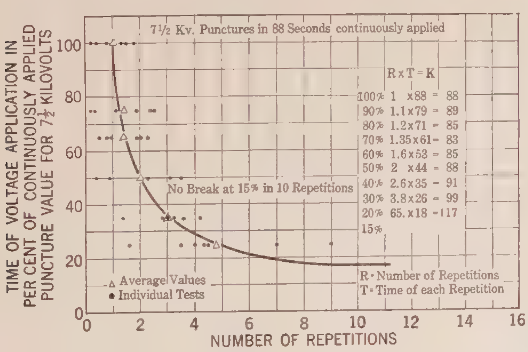

FIG. 16—EFFECT OF REPEATED HIGH-VOLTAGE APPLICATION ON LINEN PAPER

Insulation—8-Layers of 0.0005-in. Linen Oil-Impregnated Paper
Test Medium—Transil Oil at Room Temperature
Test Voltage—7½-kv. 60-cycle
Rest Period between Voltage Applications—One Hour
Electrodes—1½-in. by 2½-in. Aluminum Foil, held in Place between Glass Plates by Means of Spring Clamps

immersion has been found to be rapid in the first stages. In order to avoid such changes during test, the insulation after drying was therefore placed in 80 deg. cent. oil for one week before submitting to voltage stress. Furthermore, the tests, involving long rest periods between voltage applications, eliminated the possibility of using large 1½ in. brass electrodes as done in the previous cases. The following method was therefore adopted. Aluminum foil was cut 1½ in. by 2½ in. for use as electrodes. The insulation tested (0.0005 in. linen paper) was cut 2 in. by 3 in. and held in place between the aluminum terminals by means of glass plates and spring clamps. The miniature condensers so pre-

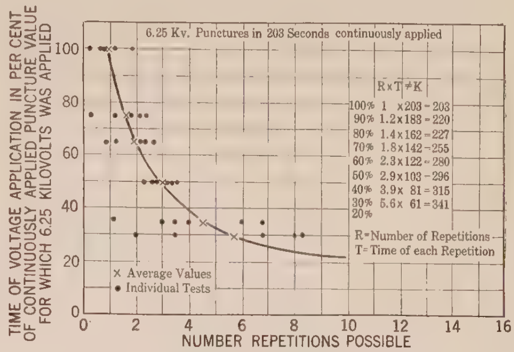

FIG. 17—EFFECT OF REPEATED HIGH VOLTAGES ON LINEN PAPER, HEATED BETWEEN APPLICATIONS

Insulation—8 Layers 0.0005-in. Oil-Treated Linen Paper
Test Medium—Transil Oil at Room Temperature
Test Voltage—6.25-kv. 60-cycle Sine Wave
Rest Period between Tests—at least one hour
Treatment between Voltage Tests—Placed in 80 deg. cent. Oil for 20 Minutes and in 20 deg. cent. Oil for at least 40 minutes
Electrodes—1½-in. by 2½-in. Aluminum Foil, held in Place between Glass Plates by Means of Spring Clamps

pared were vacuum dried at 115 deg. cent. and oil impregnated. They were then placed in transil oil at 80 deg. cent. for a period of one week, whereupon they were cooled to room temperature and the voltage tests made. The voltage repetitions in each case were followed by oil immersion at 80 deg. cent. for 20 to 30

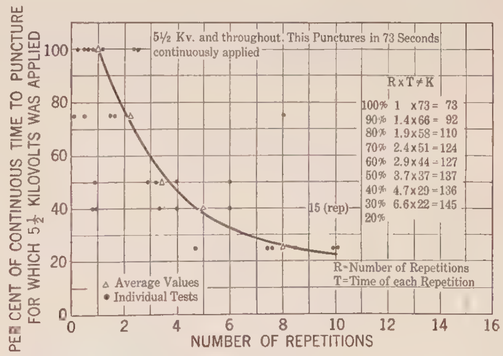

FIG. 18—EFFECT OF REPEATED HIGH-VOLTAGE APPLICATIONS ON MICA

Insulation—2 in. by 3 in. Sheets of Yellow Mica Built to Thickness of 0.004 in.
Test Medium—Transil Oil at Room Temperature
Test Voltage—5½-kv. 60-cycle
Electrodes—1½ in. by 2½-in. Aluminum Foil, held in Place between Glass Plates by Spring Clamps
Rest Period—One hour between Voltage Tests

minutes. The condensers were then quickly transferred to a cold oil tank and brought to room temperature before further voltage was applied. The period between tests was approximately one hour in all cases. Typical results are given in Fig. 16. As will be noted, the application of voltage in steps by this procedure leads to increased voltage life of the insulation as the

time of each voltage application is diminished. This is shown in the values of $R \times T$ given in Fig. 16. These results are directly comparable to those of Fig. 17. In the latter, using the same type of insulation and testing methods, except that the insulation was not heated between voltage periods, the effect of each stress application was found to be additional.

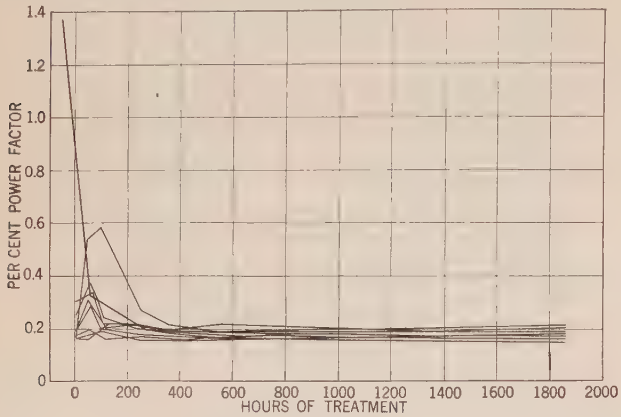

FIG. 19—EFFECT OF LOW-VOLTAGE APPLICATION ON POWER FACTOR

Insulation—8-Layers of 0.0005-in. Linen Oil-Treated Paper
Test Medium—Transil Oil at Room Temperature
Test Voltage—3300-volts 60-cycle
Electrodes—1½-in. by 2½-in. aluminum Foil, held in Place by Spring Clamps between Glass Plates

As contrasted to the results obtained with oil treated fibrous insulation, miniature condensers, similar to those used in Case IV above, were made up using mica as insulation. The typical results are shown in Fig. 18. As will be noted, with voltage application in steps, an apparent increase in dielectric life is obtained with or without heating in oil between tests, *i. e.*, the product of $R \times T$ in Fig. 16 is not constant, but increases as the time of each voltage application is diminished.

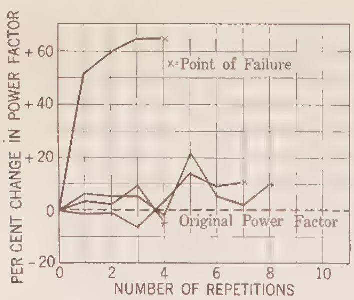

FIG. 20—EFFECT OF HIGH-VOLTAGE APPLICATIONS ON POWER FACTOR

Insulation—8-Layers of 0.0005-in. Oil-Treated Linen Paper (2 in. by 3 in.)
Test Medium—Transil Oil at Room Temperature
Test Voltage—8-kv. 60-cycle, held for 20 sec. which was 40 deg. of the Time to Puncture when continuously Applied
Electrodes—1½-in. by 2½-in. Aluminum Foil, held in Place between Glass Plates by Spring Clamps

EFFECT OF VOLTAGE APPLICATION UPON POWER FACTOR VALUES

The effect of voltage application upon per cent power factor values was investigated using both low and high stresses. In all cases the investigation was carried out by means of miniature condensers as described above, using 1½ in. by 2½ in. aluminum foil electrodes and 0.0005 in. linen paper made up to a thickness of 0.004 in., vacuum dried and oil impregnated at 115 deg. cent.

Case I: Applied voltages producing no puncture for indefinite time.

The results shown in Fig. 19 indicate power factor determinations at 1000 cycles (bridge method) made between voltage applications of 3300 volts on linen paper insulation prepared as described above. The voltage gradient, 825 volts per mil, produced no puncture of the insulation within the limit of the experiment, 77 days. Aside from the power factor variations during the initial stages of the experiment, no change was noticed.

Case II: Applied voltages of relatively high stresses producing puncture when continuously applied within a period of 15 minutes.

The effect of relatively high stresses intermittently applied upon the per cent power factor at 1000 cycles (bridge method) leads to extremely erratic results. In general, the effect shown in Fig. 20 is obtained.

GROUNDING LIGHTING CIRCUITS

The grounding of electrical circuits supplied from the low voltage side of transformers is recommended as a safety precaution by Dr. M. G. Lloyd, Chief of the Safety Section of the Bureau of Standards. In a paper presented at the meeting of the International Association of Municipal Electricians, Dr. Lloyd pointed out that grounding reduces the danger of fire and accident by preventing the occurrence on the circuit of voltages higher than expected, such as might result from lightning or from crosses with a high-voltage line. Secondary circuits carrying less than 150 volts should always be grounded, he states, and grounding is desirable also for circuits as high as 440 volts.

Grounding to water-piping systems is considered by far the best where such systems are available, and the objections sometimes urged against this procedure are considered unimportant. Such objections include the likelihood of electrolysis, the danger to employees, and the possibility of overheating the pipes. There is, however, no evidence showing that these objections are valid.

Grounding of electrical circuits to gas pipes should never be done, he states, as such pipes do not have freely conducting joints and the gas they contain is, of course, a nonconductor. Where water-piping systems are not available, recourse should be had to artificial grounds. Where soil conditions are not suitable for artificial grounds the use of a system ground wire is suggested. To maintain grounding connections properly, systematic inspection and testing are recommended.

The grounding of secondary circuits may be done either at the transformer or at the building entrance of the service according to the local regulations. Grounding at both places is recommended, thus insuring a multiplicity of grounds on every secondary circuit.

Complete Synchronous Motor Excitation Characteristics

BY JOHN F. H. DOUGLAS,[1] ERIC D. ENGESET[2] and ROBERT H. JONES[2]
Associate, A. I. E. E. Enrolled Students of A. I. E. E.

Synopsis.—Synchronous motor excitation characteristics published hitherto have been incomplete. If theoretically determined, while forming closed loops, some doubt as to their accuracy has been entertained. When determined experimentally, thay have not been complete, in that the so-called unstable portions of the curves have not been obtained, and generally speaking, the upper portions of the characteristics have been missing.

This paper shows complete synchronous motor characteristics, experimentally determined, differing materially from published curves determined by theory. These differences are discussed, and their cause attributed to variations in synchronous impedance.

Experimental data is included showing the factors on which synchronous impedance depends, and how it varies with current, saturation and power-factor.

The excitation characteristics of a synchronous motor, more familiarly known as the *V* curves are well known. As determined from test they are incomplete, *i. e.* lacking portion corresponding to the larger armature current values. In Fig. 1 is reproduced a set of complete excitation characteristics, calculated by Dr. C. P. Steinmetz and shown in his "Alternating Current Phenomena" page 434. These curves are closed loops. Quoting from page 437, we read, "The upper parts of these curves, however, I have never been able to observe completely and consider it probable that they correspond to a condition of synchronous motor running which is unstable. The experimental observations usually extend about the lower portion of the curves, and in trying to extend the curves further to each side the motor is thrown out of synchronism." The writers know of no published experimental data covering the unstable portion of these curves.

Dr. Steinmetz did not regard these curves as accurate for he says, "It must be understood, however, that these power characteristics can be considered as approximations only, since a number of assumptions are made which are not, or only partly, fulfilled in practise." For instance Fig. 1 indicated that a synchronous motor will not carry any load with the field circuit open. Dr. Steinmetz says "So by decreasing gradually the excitation, and thereby the e. m. f., the curves, at light load, occasionally are extended below zero, into negative values of voltage, while the power still remains constant and positive as a synchronous motor. In other words, the motor keeps in step even if the field excitation is reversed; the lagging component of the armature reaction magnetizes the field, in opposition to the demagnetizing action of the reversed field." We do not recall any experimental data published which shows the distortion actually occuring in the left hand corner of the curves in Fig. 1.

The object of our experiments was to obtain the complete excitation characteristics of a synchronous motor, unstable as well as stable portions, and the complete closed loops if possible, and to observe the manner in which the curves are distorted for small and reversed excitations. We hoped that the instability was of a purely mechanical nature, for then we might succeed in stabilizing the motor by coupling it to another synchronous motor. We had, fortunately, in our laboratory, a 15 kv-a., 6 pole, 1200 r. p. m., synchronous set consisting of two identical machines, made by the Westinghouse Company for educational institutions. One of the machines had a stator that could be rotated around the shaft as an axis, either by a hand wheel, or freely within limits. The stator of this machine carried a two foot arm for weighing the

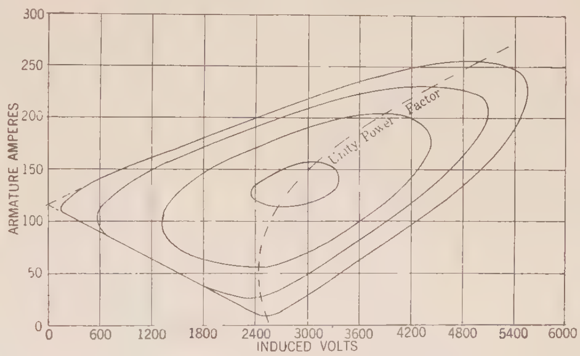

Fig. 1—Synchronous Motor Characteristics After Steinmetz

torque by the reaction method. We connected the machine according to Fig. 2. The projecting arm of the movable stator was supported on a jack-screw, which was in turn supported on small platform scales.

In Fig. 2 the motor at the right was the one tested. Although connected for 3 ϕ, *Y*, and 230 volts, it was run at reduced voltage by a bank of auto-transformers. It was run first at 115 volts, later at 55 volts, and finally at 20 volts, impressed voltage. The motor at the left was run at 230 volts, and was succesful in all cases in keeping the other machine from falling out of step. When supplied with current the movable stator tended to rotate, and we were able to measure the reaction

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torque successfully. The left hand motor was first started. The right hand machine was then excited to transformer voltage. S_2 was then closed. Before closing S_1 the movable stator was swung into such

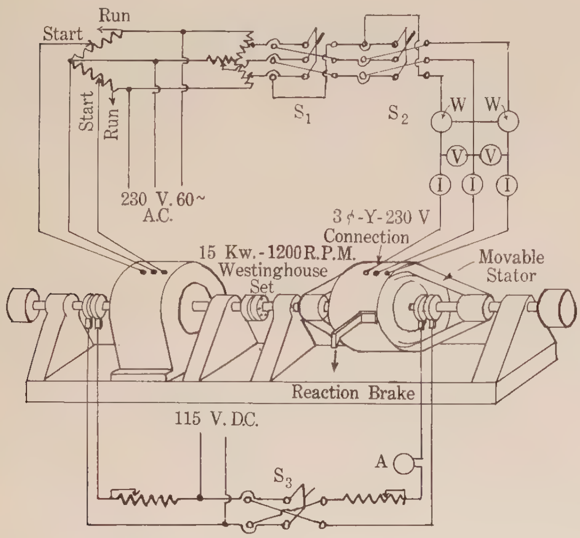

Fig. 2—Connections for Test on Complete Synchronous Motor Characteristics

a position that the phase of the induced voltage was the same as that of the line when a voltmeter across switch S_1 indicated no voltage. Then switch S_1 was closed,

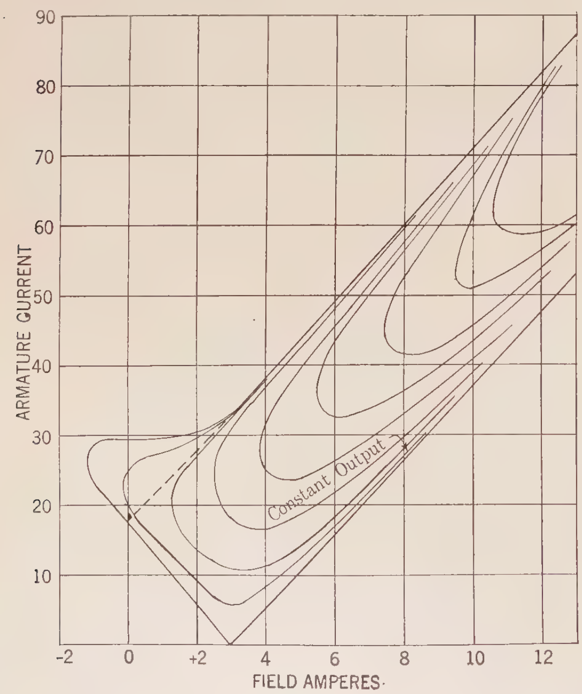

Fig. 3—Complete Excitation Characteristics of 15 Kv-a., 1200 R. P. M., Westinghouse Synchronous Motor at Half Normal Voltage

and as might be expected practically no current flow resulted, and no torque was produced.

When a synchronous motor is loaded, the rotor drops back in phase, this in turn, causes the motor to draw an increased current, and usually a larger torque is produced enabling the motor to carry its load. However, when the increased current gives a smaller torque, the motor will stop. In place of allowing the rotor to fall back in phase, we advanced the stator with the jack screw. We found that advancing the stator in the direction of rotation, the current and watts increased continuously. At first the torque also increased, but it reached a maximum, and then an advance of the stator phase resulted in a lower reading on the scales. We were able to reduce the torque again to zero in this way, in every case. This shows conclusively that we were observing points on the so-called unstable portions of the characteristics.

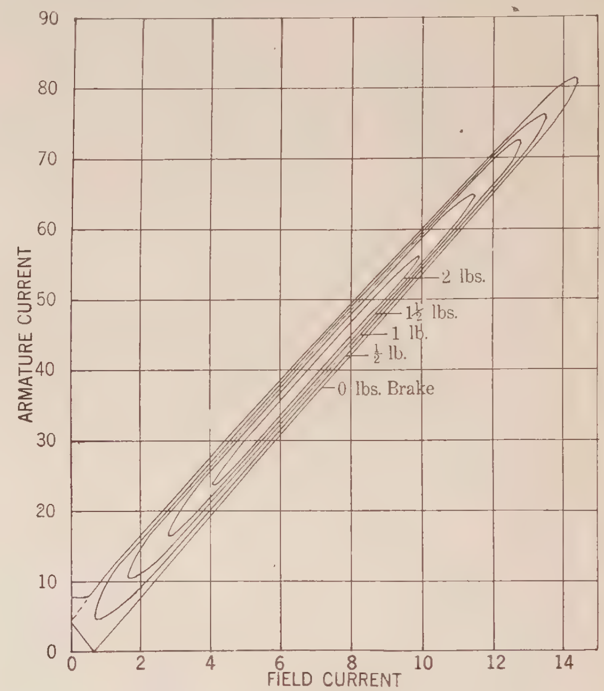

Fig. 4—Complete Excitation Characteristics of 15 Kv-a., 1200 R. P. M., Westinghouse Synchronous Motor at 20 Volts

We were able to shift the phase of the stator sixty electrical degrees by the jack-screw. By reversing switch S_1 or S_2 we were able to advance or retard the phase 120 deg., by reversing S_3 and either S_2 or S_1 we were able to advance or retard the phase 60 deg. We made a number of runs at each voltage. Most often we held the field current constant for a given run, and varied the phase reading, phase angle, torque, volts, watts, and armature current. The readings were then corrected and reduced to a standard voltage and plotted.

The characteristics obtained at 115 volts (and at 55 volts adjusted to 115 volts) are shown in Fig. 3. The nose-shaped protuberance on the curves for reversed excitation is to be noted. The upper portion or unstable portion of the curves seems to have been obtained however, no evidence of the curves forming loops is shown.

In an endeavor to obtain closed loops, tests were made at an impressed voltage of 20 volts. The results of these tests are shown in Fig. 4. The loops are now closed. The maximum torque occurred at 7 amperes in the field, and 40 amperes in the armature, and was 2.13 lb. Fig. 4 is somewhat surprising, in that the loops are very long and narrow, and with practically straight sides. No evidence of a saturated condition is observed with large field currents. Dr. Steinmetz, in the place quoted, expressed a fear that saturation would affect the shape of the curves, which does not seem to be realized.

The peculiarities in the shape of the characteristics here shown, may be attributed possibly to the following assumptions used by Dr. Steinmetz, and acknowledged by him to be inaccurate. "While the reactance of the line is practically constant, that of the motor is not but varies more or less with the saturation, decreasing for higher values." "Furthermore, this synchronous reactance usually is not a constant quantity, even at constant induced e. m. f., but varies with the position of the armature with regard to the field; that

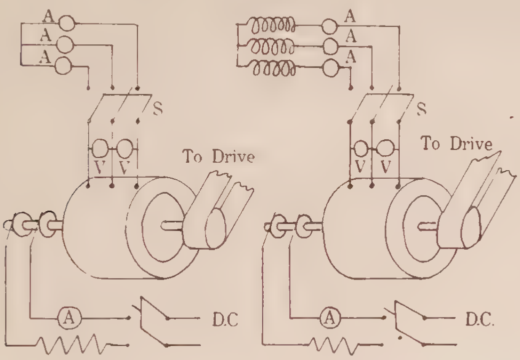

FIG. 5 FIG. 6
SYNCHRONOUS IMPEDANCE TESTS

is, varies with the current and its phase angle. While in most cases the synchronous reactance can be assumed constant, with sufficient approximation, sometimes a more complete investigation is necessary, consisting in the resolution of the synchronous impedance into two components, in phase and in quadrature, respectively, with the field poles. Especially is this the case at low power factors." He here mentions the example of a synchronous motor remaining in step with light loads and reversed excitations as coming under this case, and which Fig. 3 verifies.

We draw from the above data the following conclusions:

1. The unstable portions of the synchronous motor characteristics can be obtained by directly connecting the motor to another rated at the same speed.

2. The torque can be conveniently measured by the reaction method if the stator is swung from bearings and free to turn about the shaft.

3. Complete characteristics (closed curves) can be observed if the motor is tested at a greatly reduced voltage. The curves for one voltage are similar to those obtained at another except for scale.

4. Anomalies in the shape of the characteristics have been observed at light loads, with small and with reversed field excitations.

5. Further tests to determine the amount of variation in the synchronous impedance, with saturation, current, and phase angle, was thought desirable, in view of the anamolies observed, and the attributing of variations in shape from Fig. 1 to this quantity by Dr. Steinmetz.

VARIATIONS IN THE IMPEDANCE OF A SYNCHRONOUS MOTOR AT SYNCHRONOUS SPEED

A common method of measuring the synchronous impedance of a motor or generator is shown in Fig. 5. The voltage induced in the machine is measured with the switch S open, the motor being driven at synchronous speed, and separately excited. The current on short circuit is measured with the switch S closed, the field current being unchanged. The synchronous impedance is taken as the ratio of cause to effect, of open circuit voltage to short circuit current. The impedance obtained in this way is much too large. Since the armature reaction destroys the saturation of the machine, this test does not give the equivalent impedance at higher values of saturation.

Another method of finding the synchronous impedance is shown in Fig. 6. The voltage with S open is called E_o, that with the switch closed, E_1, the current being I. The impedance may be taken as the ratio of cause to effect, but the cause of current flow is the unbalanced voltage $(E_o - E_1)$. The impedance is $Z = (E_o - E_1)/I$. This method is superior to that in Fig. 5, in that we have two controls, the field resistance and the choke coils. We are thus able to obtain the synchronous impedance at different saturations, and, if we desire, at different currents as well. This is the method on which the A. I. E. E. standard is based. This method gives no clue as to how the impedance varies with power factor, since the current is always at very low power factor.

In order to determine the variation of synchronous impedance with current, saturation and power factor, three controls should be available, and these were available in the Westinghouse set, in the two field rheostats, and in the phase displacement hand wheel attached to the machine with the movable stator. The two machines were coupled together and driven by a d-c. motor at 1200 rev. per min., and connected as in Fig. 7. First both machines were excited equally, then the adjusting handwheel was turned until the voltmeter $D E$ indicated no voltage, The angular position of the movable stator was then noted on a degree scale mounted on its frame.

If either the phase position of the movable stator,

or the relative field excitations were changed, the voltmeter across the switch indicated a resultant voltage $D\,E$, which was taken as the cause of the flow of current resulting when the switch was closed. The reactions of this current equalized the fluxes in the two machines and the terminal voltage E when the switch S was closed was taken as the measure of the saturation. The synchronous impedance was taken as the ratio of cause to effect, or $Z = (D\,E/I)$. By unbalancing the voltages more and more different circulating currents could

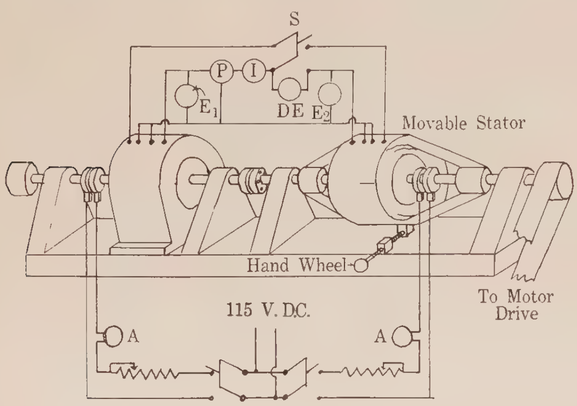

FIG. 7—IMPROVED SYNCHRONOUS IMPEDANCE TEST

be obtained. By increasing both fields together different saturations could be obtained. By controlling the phase relation of the circulating voltage through the combined use of the hand wheel and the field rheostats, currents of any power factor could be circulated. The power factor was taken as the ratio of the wattmeter reading P to the product $E\,I$. When the voltage was unbalanced by field excitation only, (the stators being in phase) the resulting current had a very low power factor, 8-10 per cent. When the

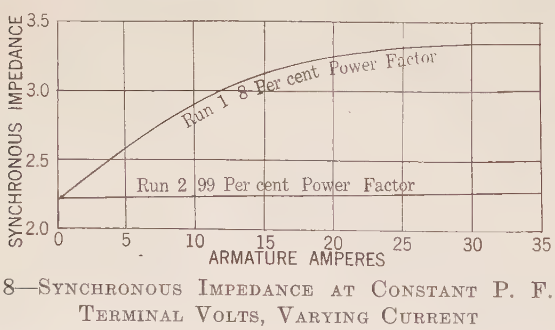

FIG. 8—SYNCHRONOUS IMPEDANCE AT CONSTANT P. F. AND TERMINAL VOLTS, VARYING CURRENT

voltages were unbalanced by the hand wheel only, the fields being equal, the resultant current had a very high power factor from 99-100 per cent. Six readings were taken for each point of data, the voltage E_1, E_2 and $D\,E$, with S open and E, I and P with S closed.

In the first two runs the terminal voltage on closed circuit E was held constant at rated value 180 volts, but the voltages were unbalanced more and more, circulating different currents. In one run this was done by the field rheostats, the phase displacement between the stators being zero, and resulting in an 8 per cent power factor. In the other, this was done by the hand wheel, the machines being excited equally, resulting in a 100 per cent power factor. The results of these two runs are shown in Fig. 8. An increase of

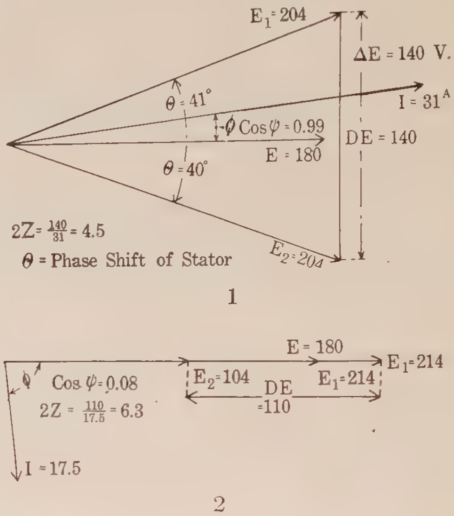

FIG. 9—VECTOR DIAGRAMS RUNS 1 AND 2

impedance with current at low power factors is indicated. A considerably lower impedance is shown for 100 per cent power factor than for low power factors. The impedance at 100 per cent power factor seemed to be independent of the current strength. Two points are shown, one on each curve for which vector diagrams are given in Fig. 9. One curious result shown in this figure is that the terminal voltage on closed circuit E is greater than the average of E_1 and E_2 for low power

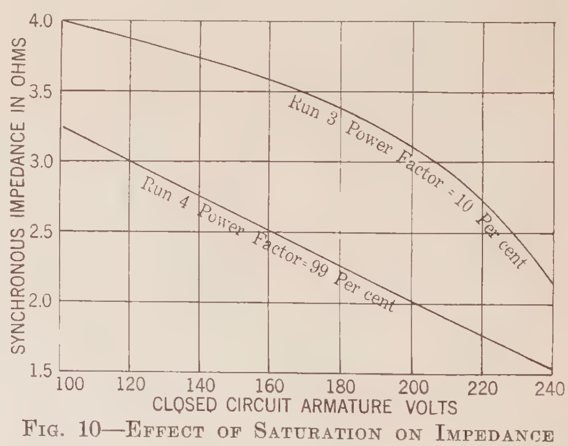

FIG. 10—EFFECT OF SATURATION ON IMPEDANCE

factors, but less than the vectorial average of E_1 and E_2 for high power factors. This indicates that our test gives simply an average impedance of the two machines.

In the next two runs the power factor was again kept constant, but the saturation of the machines was varied. In the third run the two machines were kept at zero relative phase, the power factor was 10 per cent, and the circulating current was kept at rated

value on the name plate of the machine. In the fourth run the phase displacement of the machines was kept constant at 41 deg., and the power factor was 99 per cent. The results of these two runs is given in Fig. 10. A decrease in impedance with saturation is indicated, as well as a lower impedance at 100 per cent than at low power factors. The decrease in the impedance with saturation at 100 per cent power factors is believed to be a novel result. The ratio of impedance at normal voltage namely impedance at 100 per cent

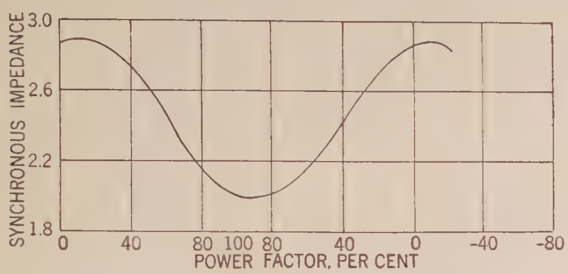

Fig. 11—Effect of Power Factor on Impedance-Current and Saturation Constant

power factor to impedance at zero power factor is as 2 as to 3. This ratio is considerably higher than that obtained by purely mathematical calculation as for example in Karapetoff's "Magnetic Circuit" pages 150 and following.

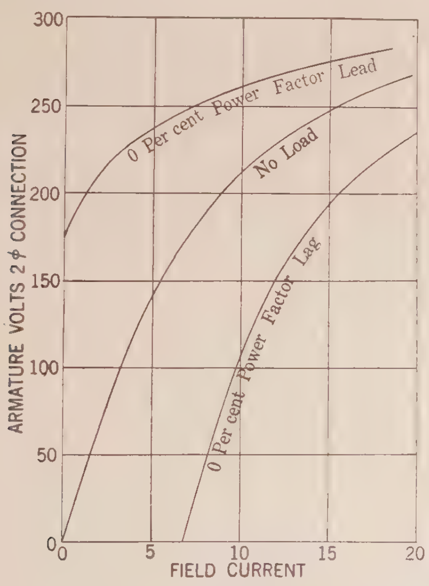

Fig. 12—Saturation Curves

In the fifth run the saturation was kept constant at a terminal voltage of 180 volts, the circulating current was kept constant at (2/3) of name plate rating, but the power factor was varied from 90 deg. lag to 90 deg. leading current. The results are shown in Fig. 11. A variation of very considerable amount with power factor is indicated. The saturation curves of the machine at no load, and full load zero power factor both leading and lagging are given in Fig. 12 as a matter of interest.

The variation in synchronous reactance with saturation is satisfactorily allowed for in the magneto-motive force method, and in the A. I. E. E. method of figuring synchronous machine performance as well. The Blondel method of computing performance, explained by Professor Karapetoff in his "Magnetic Circuit" pages 150-157, provides a satisfactory method of allowing for the effects of saturation, and also power factor, with two exceptions. First, as noted above, impedances at 100 per cent power factor seem to be larger than those indicated by the "Magnetic Circuit." Secondly, according to Professor Karapetoff, the impedance at 100 per cent power factor, should be independent of of saturation. This is conclusively disproved by our experiments.

We do not have any theory to propound that will harmonize the variations here noted, but we believe that the Blondel method can be improved so as to allow for the effects of saturation with high power factor currents. Furthermore, we hope, that when such a theory is found it will completely explain the queer nose we have observed and recorded in our Fig. 3.

CORRESPONDENCE

To the Editor:

Referring to the paper on Three-Phase Wattmeter Connections, by Philip Chapin Jones, published in the Journal for April 1924:

For the past two years I have used and taught the Kouwenhoven Test for checking the correctness of the connections of polyphase watthour meters and, although it is not all that is to be desired from the standpoint of a rule of thumb check, it still is, in my opinion, the nearest approach to such a check that has as yet been proposed.

In applying the test, however, it must clearly be understood just what is meant by the interchange of leads 1 and 2. The interchange of leads 1 and 2 means the interchange of those leads that are connected to the line wires which furnish current to the current coils of the meter, and not necessarily terminals 1 and 2 at the meter itself. In other words, the designation 1 and 2 refers to line wires containing current transformers, which in Dr. Kouwenhoven's original paper were numbered 1 and 2, and not to meter terminals.

For instance, in the example chosen by Mr. Jones (group 2) we would have two interchanges possible under this interpretation of what is meant by leads 1 and 2. In one of them we would get, after the interchange $E_{2-3}\, I_2 \cos{(30 - \theta)}$ and $E_{12}\, I_3 \cos{(90 - \theta)}$. In the other we would have $E_{22}\, I_2 \cos{(30 - \theta)}$ and $E_{13}\, I_3 \cos{(30 - \theta)}$.

Now neither of these combinations will cause the meter to stop. If this interpretation is put on the meaning of leads 1 and 2, I know of no wrong connections that will cause the meter to stop after the interchange.

Donald T. Canfield

A Study of Direct-Current Corona
in Various Gases

BY F. W. LEE*
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and

B. KURRELMEYER*
Non-member

Synopsis.—*1. The critical corona intensities have been determined for helium, hydrogen, oxygen, nitrogen, air, and carbon dioxide for pressures ranging from 2 to 760 mm.*

2. In each case the relation $\frac{E}{P} = A + \frac{B}{\sqrt{P}}$ *was found to hold approximately for pressures above 4 cm.*

3. The values found for air agree well with those found by Whitehead and Isshiki from their investigation of alternating-current corona.

4. No simple relation could be found giving the correction between $\frac{E}{P}$ *and* $\frac{1}{\sqrt{P}}$ *over the whole range of pressure.*

5. The influence of temperature on critical corona intensity was investigated for hydrogen, and found to consist merely of a change in δ, as was expected.

6. It is shown that the data obtained do not permit the explanation of corona as a process of ionization by collision, unless we make further assumptions. The nature of the assumptions necessary is not evident.

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1. Introduction

THE law of formation of corona on wires is an empirical relation which was first developed about 15 years ago by Whitehead. The electric intensity at which corona forms on a circular wire coaxial with a circular cylinder is given by the relation

$\frac{E}{\delta} = A + \frac{B}{\sqrt{\delta r}}$, where δ is called the density factor: $\delta = \frac{3.92\,P}{T}$ A and B are constants which depend on the kind of gas and on the polarity of the wire. P is the pressure of the gas in centimeters of mercury. T is the absolute temperature, and r is the radius of the wire, in centimeters.

The corona law was developed experimentally for alternating potentials by Whitehead, Peek and others. Whitehead[1], was the first to determine both the exact influence of the radius of the wire and the constants. Peek[2] considering the influence of temperature, first established the density factor δ. Farwell[3], and later Whitehead and Brown[4] determined the constants A and B for continuous potentials by changing r. Whitehead and Isshiki[5] found that for alternating-current corona there was a break in the linear relation between E and $\frac{1}{\sqrt{\delta\, r}}$ at a definite value of ($\delta\, r$.) This value of ($\delta\, r$) was found to be the same as the value at which the straight lines for positive and for negative corona crossed. Whitehead and Isshiki also investigated the influence of temperature for alternating-current corona, while Whitehead and Lee did the same thing for direct-current corona, Whitehead[1] had previously shown that the moisture content of the air had no effect on the critical intensity.

Townsend[7] derived the relation $\frac{E}{P} = A + \frac{B}{\sqrt{P\, r}}$ from the laws of sparking between parallel plates, introducing the assumption that ionization by collision takes place out to a certain distance from the surface of the wire, where the electric intensity is constant. Even if we admit this assumption, Townsend's analysis has no way of distinguishing between positive and negative corona, and it does not account for the departures found to exist for low values of ($\delta\, r$.)

Davis and Breese[8] investigated the continuous corona in hydrogen. They found that whereas in air, for the higher values of ($\delta\, r$), negative corona occurs at higher values than positive corona, the reverse was true for hydrogen. The purpose of the present investigation was to determine the critical corona voltages for a number of different gases over a wide range of pressure, and to determine, if possible, what physical processes are involved in the formation of corona.

2. Description of Apparatus

The apparatus was similar to that used by Whitehead and Lee[6] and is shown in Fig. 1. In preliminary experiments it was found that there was a small fluctuation in the continuous potential at the corona tube, the amplitude of which varied with the frequency of the generator voltage. To eliminate this fluctuation, the capacity between the kenotron and the corona tube was increased to 0.1 microfarad, and an inductance of 143 henries was placed in the same circuit. Under these conditions the fluctuation was reduced to a negligible quantity in the range of frequencies used, (500 to 600 cycles). This is shown by the following table of observed corona voltages:

Frequency	Volts
60	133.0
133	135.0
600	135.6

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*Of John Hopkins University, Baltimore, Md.

1. For references see Bibliography.

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 9-12, 1925.

The voltage fluctuation to be expected was calculated from the formula given by Hull[9] to be about 0.5 per cent, without the large inductance. Oscillograms taken with the inductance in series showed no noticeable fluctuation.

For convenience in manipulation the kenotron, together with the filament battery, condensers, choke coils, and the multiplier resistance for the corona-voltmeter, was separated from the remainder of the apparatus and placed on a well-insulated wooden platform, directly above the transformer and the corona tube.

The corona tube. The corona tube was the one used by Whitehead and Lee[6]. The main chamber was made from a piece of 6-in. steel piping, 19 in. long, carefully bored out in a lathe to receive the supports for the

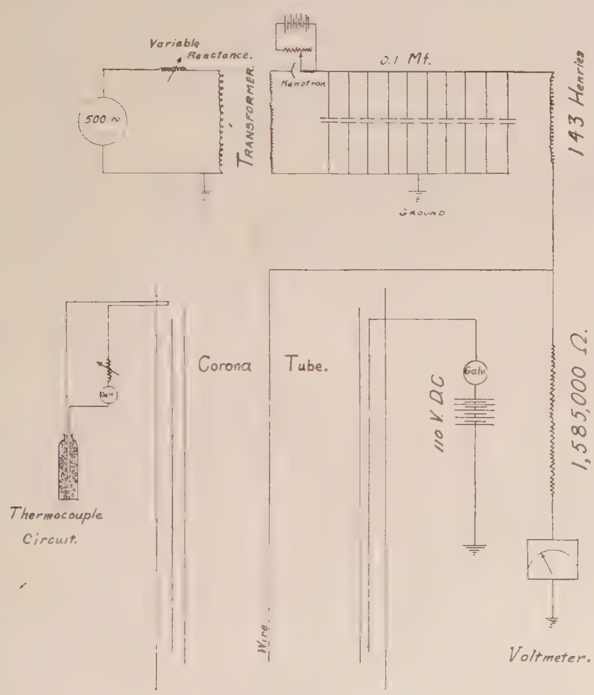

FIG. 1

concentric cylinders. The inner cylinder was of heavy brass, and had a number of small perforations. Its inside diameter was 3.75 in. = 9.52 cm. Two caps of bakelite in the form of crosses were machined to fit tightly around the ends of this cylinder, and the wire used in the corona measurements was stretched through small holes carefully centered in the caps, and was held taut by lock-nuts. In this way it was possible to remove the wire without removing the lower end of the tube.

3. Calibration of Instruments and Accuracy of Measurements

The voltmeters used to measure the corona voltage has been calibrated and found to be accurate within the error of observation. These limits were ± 3 volts for the Siemens-Halske voltmeter and ± 10 volts for the Weston (used only above 7000 volts). The limits within which the corona voltage could be determined varied from ± 5 to ± 30 volts at the two ends of the range. At pressure 1-5 mm. the initial deflection was very large, ranging from 10 cm. to complete off-scale. For pressures ranging from 20 cm. up to atmospheric pressure, and especially for positive corona, the initial deflection was only one mm. or less. Hence the accuracy of observing the critical voltage is less at the higher pressures; but the percentage accuracy is about the same, namely 0.5 per cent.

Since it was necessary to use pressures both above and below atmospheric pressure, the manometer was of the open-tube type; a wooden meter-bar was mounted between the two manometer columns served as a scale. The barometric pressure was taken to the nearest hundredth of a centimeter. Since the scale of the barometer was accurate at 0 deg. cent., a correction had to be applied to the observed barometric readings to reduce them to scale readings at 0 deg. cent. A similar correction was applied to the wooden meter-bar. The final accuracy of the pressure readings is considered to be about ± 0.04 cm.

The galvanometer used to detect the beginning of corona was made by Leeds and Northrup, and had a resistance of 10 ohms. Its current constant was determined with a standard shunt and milliameter. The mean of several determinations gave one cm. scale deflection = 2.8×10^{-8} amperes. A deflection of two millimeters or more was considered an indication of corona.

4. Materials

a. Wires. Several different wires were made up from steel wire of diameter 0.0663 cm. The specimens chosen were free from kinks and surface irregularities, and were tested for variations in diameter with a micrometer caliper. They were then cut to the required length, 25 cm., and were mounted in the tube between brass rods of about two millimeters diameter. The surface was polished with fine emery cloth and soft leather. It was found that the surface conditions of the wire were affected by the corona, and so a steel wire with a chemically deposited surface of copper was tried and found unsatisfactory. The wire used in most of the experiments was a steel wire on which a thin layer of gold had been deposited electrolytically. This wire was polished with jewellers' rouge, and with soft leather. The surface so obtained was affected very little by chemical action in the corona. The data finally selected were taken partly with the gold wire, partly with the steel wire, and were always taken with a freshly polished wire.

b. Gases. In every case the only purification of the gaseous material which was attempted was the removal of water vapor. This was effected by passing the gases through a series of tubes containing calcium chloride and phosphorous pentoxide. In the earlier experiments sulphuric acid was used as a drying agent, but was found unsatisfactory.

Hydrogen and oxygen were made electrolytically in the generator shown in Fig. 2. Various electrodes, current strengths and electrolytes were used, but no corresponding variations in the corona characteristics were detected. Hence the influence of any impurities depending as to their amount on the conditions of generation was considered negligible.

Hydrogen, oxygen, nitrogen, CO_2 and helium, were obtained commercially. The hydrogen was made electrolytically, the oxygen and nitrogen by fractionation of liquid air.

The air used was laboratory air passed through the drying train, which also contained provisions for removing the coarser motes and dust particles.

The amounts of the impurities in the various gases were stated by the manufacturers to be as follows: hydrogen, nitrogen, oxygen, less than one per cent: CO_2, less than one-half per cent: helium, about five per cent nitrogen (estimated).

Pressure changes were always extended over a period of time ranging from two to five minutes, depending on the amount of gas to be admitted. The time interval between cutting off the gas supply and reading the critical voltage was also several minutes. Since the

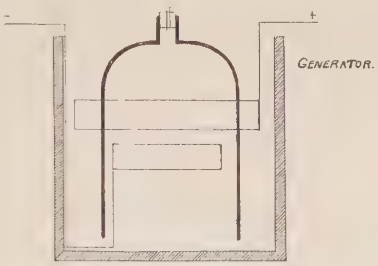

Fig. 2

volume of gas admitted was small and the heat capacity of the corona tube very large, no initial temperature fluctuation of as much as ½ degree cent. was ever observed; and with the time allowance given, temperature variations from point to point in the gas were certainly very much less than 0.5 deg. cent. In taking observations of the critical intensity, the heating effects due to corona were carefully avoided. The error introduced by temperature variations was always less than the other experimental errors.

5. Results

a. Appearance of the Corona. With the wires used, all of which had a diameter of approximately 0.0665 cm., the appearance of light was simultaneous with the first galvanometer deflection due to ionization. This was true for all conditions of pressure and temperature within the range of these experiments, and for all the gases examined.

With the wire positively charged, the corona glow was uniform around and along the wire, and was confined to a region very close to its surface. The extent of this region did not vary with pressure or current density, except that above a certain voltage there was a small brilliant intermittent discharge across from some point near the middle of the wire, to the tube. The rest of the wire retained its uniform glow.

With the fire negatively charged, and a pressure of 2-5 mm., the first corona deflection was sometimes jerky, and the corresponding flow was a faint flicker which was not restricted to any point or points; but was uniform along the wire. A slight increase in voltage brought out the steady continuous glow of negative corona. This was much more diffuse than the positive glow. A further increase of 50 to 100 volts brought out the first faint beads. These were localized discharges on the wire, and were always fairly evenly spaced, especially at higher currents. They increased in number with pressure and current density, and also varied from one gas to another. At approximately equal pressures and current densities the beads were most numerous in the gas for which the corona voltage was lowest. It was frequently observed that when the current density was increased, each new bead appeared approximately midway between two old ones. If the corona was run for a few minutes with the beads in any one position, marks were found on the surface of the wire, which looked as if they might be the result of local heating. The negative beads have been investigated in great detail by Farwell[3], Davis and Breese[8], and Crooker[11]. Their results have been found to be confirmed, in general, for all the gases investigated.

The color of the corona discharge was the same for the continuous negative and positive glow; whereas the beads were much more brilliant, and sometimes different in color. The glow was generally a pale red or purple, the color depending on the gas used, but not on the pressure or current density. In helium the discharge was yellowish; and examination with a small grating showed the presence of a yellow line, probably 5875. In hydrogen the glow was generally reddish, while in air and nitrogen the nitrogen bands predominated.

In all cases the critical voltage as well as the appearance of the corona glow was found to be independent of the material of the wire.

b. Variation of corona current with E and P. The initial corona current was always much greater and much more sharply defined for low pressures than for high pressures, and was greater for negative than for positive corona. At low pressure, (1-3 mm.), the first corona deflection was always accompanied by a sharp drop in the voltage across the tube, due to the high rate of discharge of the condensers.

Fig. 3 shows the variation of current with increasing and decreasing voltage, for various pressures and gases. The curves have the same general character in all gases, the negative curve being much steeper than the positive curve. The positive curve for decreasing voltage follows closely that for increasing voltage; in negative corona this is not the case. The negative

increasing curve has a double break, while the decreasing curve has only one, which is very well defined. The double break in the increasing curve may be due to a change in the sign of the space charge near the wire.

The actual values of the total corona current can

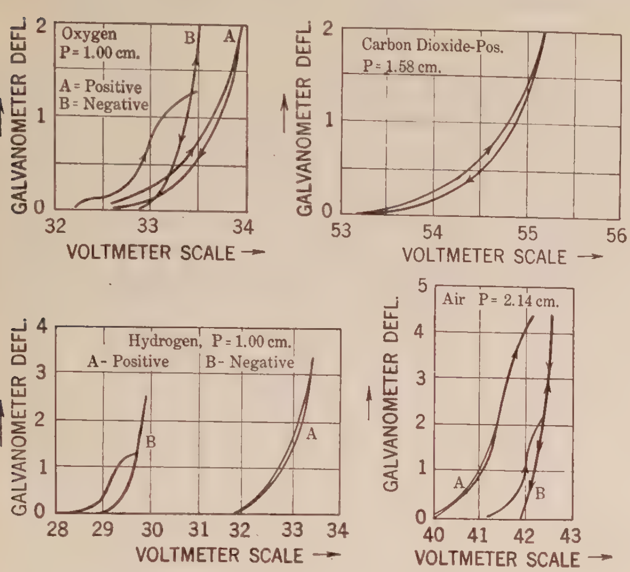

Fig. 3

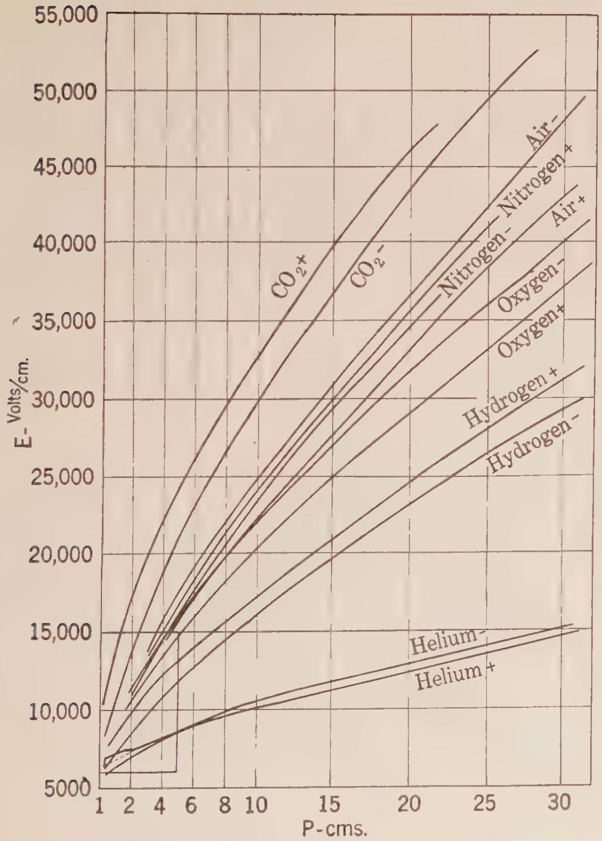

Fig. 4

only be estimated; they are of the order of 10^{-5} ampere per cm. scale deflection. The heating effect of the corona current was always negligible, because the current was never left on for a long time, No changes in pressure were to be expected from this cause. The volume of the corona tube was much too large to give any evidence of the other types of pressure change found by Kunz and his co-workers[12].

c. Variation of critical intensity with temperature. Some preliminary experiments were made with hydrogen at a temperature of 42 deg. cent. When the values of the critical voltage obtained in these experiments were reduced to room temperature (22.5 deg. cent.) by applying the density factor $\frac{315}{295.5}$, they agreed well with the values found in experiments at 22.5 deg. cent.,

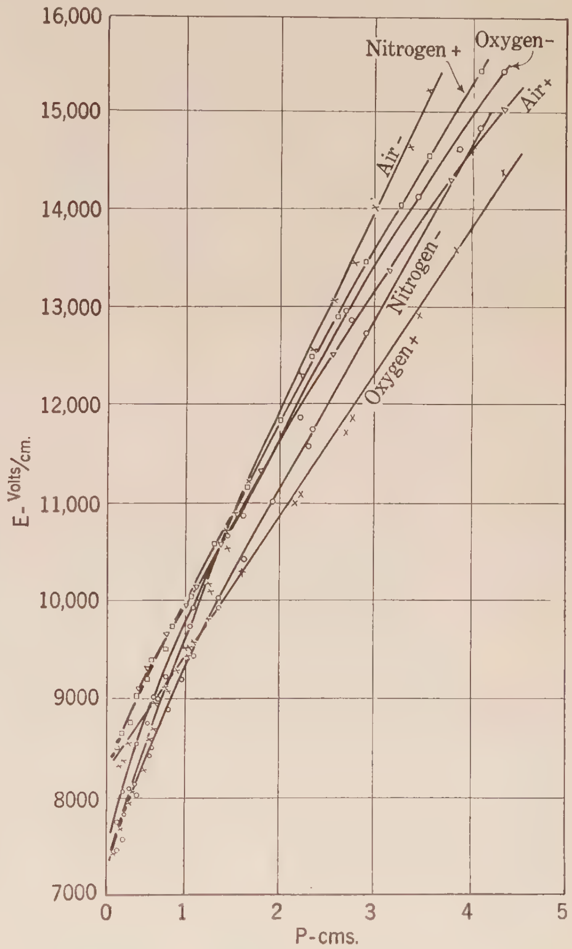

Fig. 5

except for a few points in negative corona at very low pressures. Since the same result was found by Lee for air, no further experiments with higher temperatures were made.

d. Variation of critical intensity with pressure. Figs. 4 and 5 show the variation of critical intensity with the pressure graphically. It will be seen at once that the general shape of each type of curve is the same for all gases and for both polarities.

The curves showing the relation of E to P, (Figs. 4 and 5), are not especially interesting theoretically, but they bring out several important facts. For all but the lowest pressures, $P < 1$ cm., the values of the

critical intensities are in the same order as the values of the mean free path of a gas molecule in the different gases. For all gases, when $P < 1$ cm., positive corona occurs at higher voltages than negative corona. At the higher pressures this is still true for hydrogen, nitrogen, and carbon dioxide; but in helium, air, and oxygen a crossing takes place at intermediate pressures,

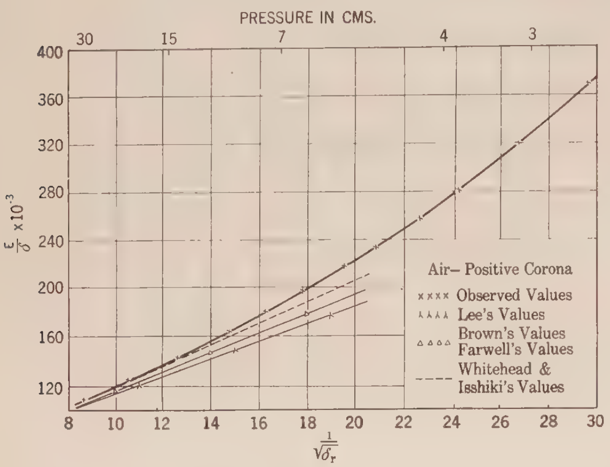

FIG. 6

so that the negative critical intensities become higher than the positive values. For $P > 10$ cms. the positive and negative curves for each gas are approximately parallel.

Fig. 5 shows, on a large scale, the E-P curves at low pressures in oxygen, nitrogen, and air. At the lowest pressures the air curves coincide with the nitrogen

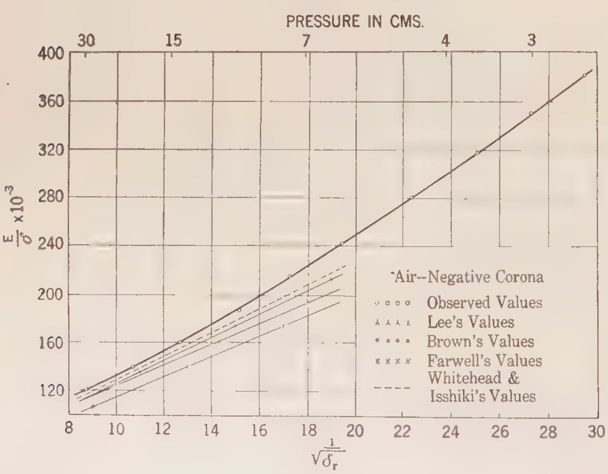

FIG. 7

curves. The positive curve for air remains intermediate between $N_2{}^+$ and $O_2{}^+$, which might be expected; whereas the negative air curve becomes higher than the negative curve for either oxygen or nirtogen; which is difficult to understand.

The curves which are most interesting historically and theoretically are those which express the relation of $\frac{E}{P}$ to $\frac{1}{\sqrt{P}}$. The law of corona formation which was established empirically by the work of Whitehead[1] and Peek[2] on air, states that this relation is a linear one:

$$E = A + \frac{B}{\sqrt{\delta\, r}}, \text{ where } \delta = \frac{3.92\ P \text{ cm}}{T_{abs.}}$$

This question has been confirmed experimentally by Farwell[3], Whitehead and Brown[2], and others for variations in r. A number of investigators has confirmed the law for variations in P, while Lee has recently confirmed it for variations in T. All this work was done on air. Davis and Breese[8] conclude that the law is approximately true for hydrogen, departures occurring for low values of P and r.

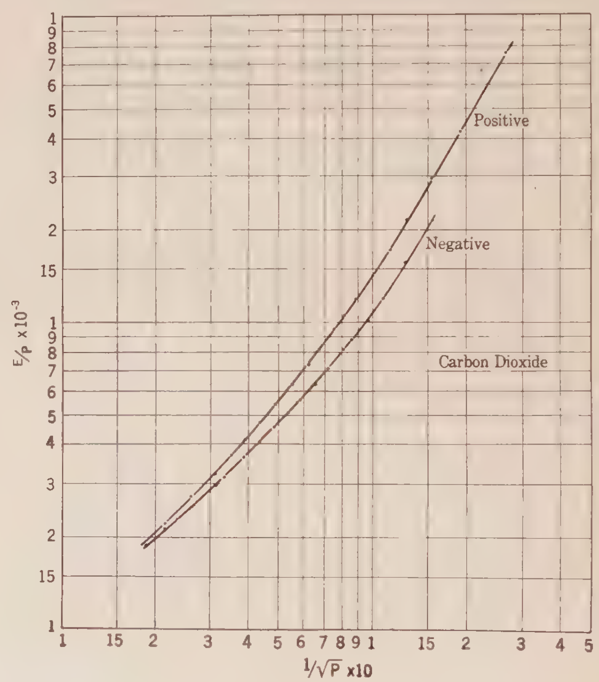

FIG. 8

Figs. 6 and 7 show how the values obtained in the present investigation compare with those obtained by Whitehead and Lee[6], Whitehead and Brown[4], Whitehead and Isshiki[5], and Farwell[3]. The agreement with the values obtained by Whitehead and Isshiki is especially good, in view of the fact that 30 cm. was both the lower limit of their range of pressure and the upper limit of the range of this investigation.

Figs. 8-13 show the relation between $\frac{E}{P}$ and $\frac{1}{P}$ plotted on logarithmic coordinate paper. In this way any power function $\frac{E}{P} = a\left(\frac{1}{\sqrt{P}}\right)^n$ appears as a straight line whose slope is n. An inspection of the curves shows that they all have two regions of small

curvature, one at the lower pressures, where the slope is very near tan 60 deg., or $\sqrt{3}$, and one at the higher pressures, where the slope is near tan 45 deg., or 1. (However, for still higher and still lower pressures, the slope passes beyond these values in some cases.) This means that there is a considerable range of pres-

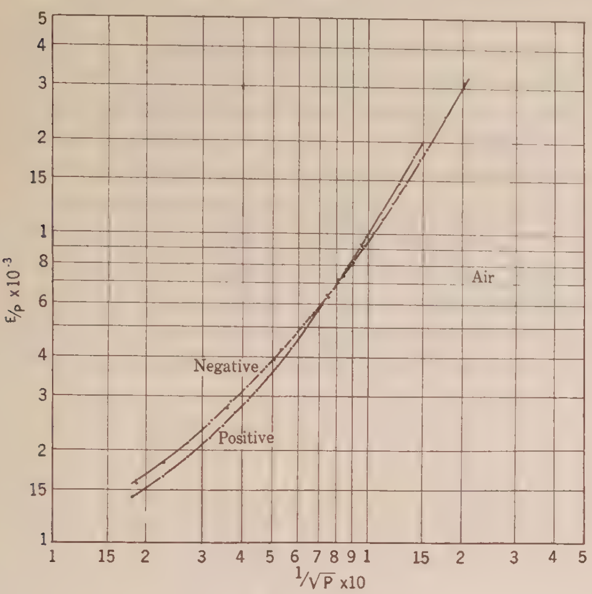

FIG. 9

sures where the relation between $\frac{E}{P}$ and $\frac{1}{\sqrt{P}}$ is very nearly linear; this happens to be the range covered by previous investigations.

All attempts to find a simple formula expressing

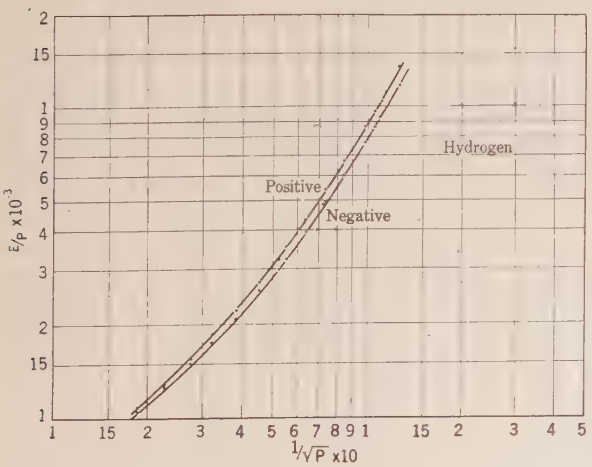

FIG. 10

the relation of $\frac{E}{P}$ to $\frac{1}{P}$ over the whole range of pressures have been unsuccessful. The most satisfactory formula seems to be $\epsilon^{A \frac{E}{P}} = \frac{B}{P}$, where A and B are constants. The agreement is not close enough, however, to warrant a calculation of the values of A and B for the different gases.

The relation $\frac{E}{P} = f\left(\frac{1}{P}\right)$ is of theoretical in-

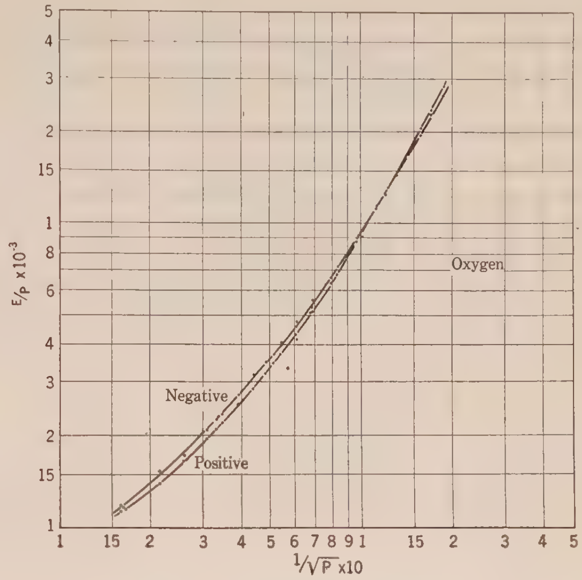

FIG. 11

terest because of the physical significance of $\frac{E}{P}$. This quantity is proportional to the energy which an ion would acquire in traversing its mean free path at

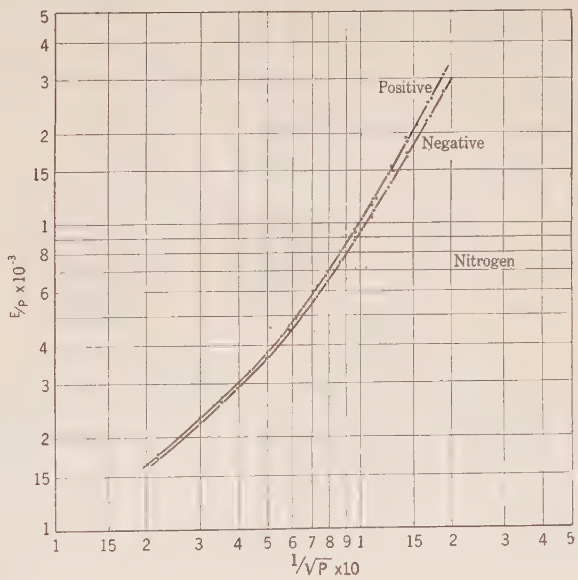

FIG. 12

pressure P in a field of intensity E. If it is assumed that corona is a process of ionization by collision, $\frac{E}{P}$ represents the energy required to ionize a gas molecule. This energy has been shown to be constant

at very low pressures; whereas within the range of this investigation $\frac{E}{P}$ is a function of the pressure. There are several possible explanations: 1. The corona process may not be one of ionization by collision. 2. The ionizing potential of a gas molecule may vary with the pressure. 3. The mean free path of the ionizing agent may not be a function of P only. 4. The E of the theoretical formula may not be equal to the actual electric intensity at the surface of the wire. 5. The ion in question may not acquire its maximum energy in the region of maximum intensity. These possible explanations will be considered in order:

1. The fact that the appearance of a glow in the gas is simultaneous with the first corona current, is strong evidence that corona is an ionization process.

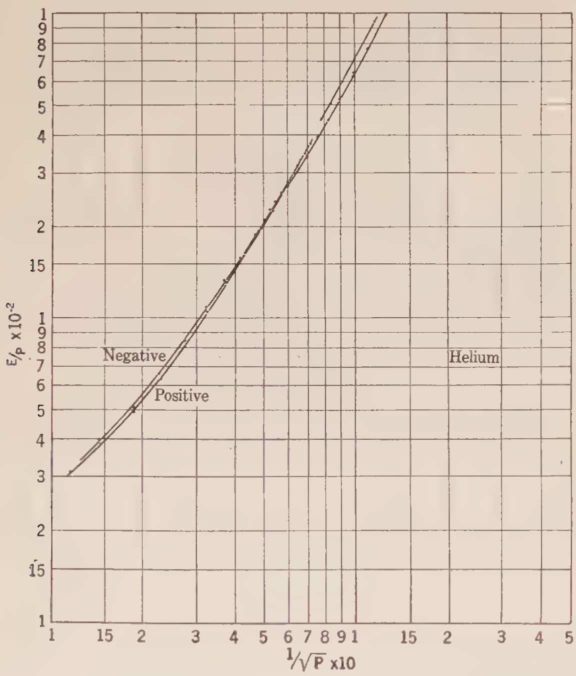

FIG. 13

2. At very low pressures the ionization energy of a gas molecule is known to be independent of the pressure. The present conceptions of atomic structure demand that this be true at all pressures.

3. For the case when the ionizing agent is an electron, the mean free path is almost certainly dependent on E as well as on P, so that this factor must be taken into consideration.

4. When there is an appreciable excess of ions of one sign over those of the opposite sign, the potential gradient at any point in space will differ from the theoretical value because of space charge effects. Before corona begins, the space charge is merely the residual ionization, and the effect is probably insignificant, so that it will not serve to explain the variation of $\frac{E}{P}$ with P. After the corona current is established, however, such an effect will certainly be present, and its amount will depend on the polarity of the wire. When this is negative, the predominating space charge may be negative at first; but eventually, on account of the great difference in the velocities of electrons and positive ions, there will be an accumulation of positive ions; which means that after a period of comparatively slow rise, the potential gradient at the wire will suddenly begin to increase very rapidly, with a corresponding increase in current, until the discharge becomes arc-like. With the positive wire the effect will be much smaller, and may amount to a decrease in potential gradient at the surface. This explains, at least qualitatively, the shape of the current curves.

5. K. T. Compton[13] has shown that electrons moving from a negative wire out to a positive cylinder acquire their maximum energy $\frac{E}{a}$ at a point $r = x$ in the space between the electrodes. x depends upon E, P and the dimensions of the wire and the cylinder. $a = k f^{1/2} p$, where k is a constant characteristic of the gas, f represents the average fraction of the average energy lost in any collision. E_x is the theoretical electric intensity at the surface of the cylinder $r = x$. The case when the wire is positive was not considered by Compton; but a simple calculation shows that the electrons attain their maximum energy at the surface of the wire. The maximum energy is still given by $\frac{E}{a}$ where $x = r_\omega$, the radius of the wire; so that the electrons acquire greater energy when the wire is positive; conversely positive ions attain their greatest maximum energy (at the surface of the wire) when the latter is negative. No matter which we assume to be the ionizing agent, it is necessary to assume a variation of f with electric intensity; in order to give the right effect, f must increase with decreasing E. This is to be expected from the definition of f. This probably involves a departure from theory in the values of the mean free path. Thus the effects considered in Sections 3 and 5 may be used qualitatively to explain the relation of $\frac{E}{P}$ to P.

The curves of $\frac{E}{P}$ against $\frac{1}{\sqrt{P}}$ for + and − corona approach each other very closely at the higher pressures, but diverge more and more when the pressure decreases. This is explained by the equations and curves of Comption (l .c. p. 342). The point x at which the ion when going out from the wire attains its maximum energy, approaches the surface of the wire

as the pressure increases; therefore $\frac{E_x}{a}$ approaches $\frac{E_\omega}{a}$; *i. e.*, the maximum energies of positive and negative corona become more nearly equal as the pressure increases. This is true no matter which type of ion we assume to be the effective ionizing agent.

The mechanism of the corona has been assumed to be a process of ionization by collision. From the general similarity of the positive and negative curves it may be assumed that the mechanism is the same, or at least very similar, for both polarities. Positive glow appears exclusively at the surface of the wire, while negative glow extends considerable distances out into the body of the gas. This points to ionization by electrons. Unfortunately, this assumption leads us to the conclusion (from section 5) that positive corona should appear at lower surface intensities; which in the majority of cases is not true. The maximum energies calculated from Compton's formulas are about 100 times the ionization potentials of the negative gases. Similar difficulties arise if we assume that positive ions are the ionizing agent. It is hard to see how this can be possible, necause the energy of the electrons present must be greater than that of the positive ions. Neither assumption can be made to explain the crossing of the two curves in air, oxygen, and helium, without some auxiliary assumptions; and of what nature these assumptions would have to be in order to explain the observed effects, is an open question.

In this discussion, nothing has been said about the possible role of the photoelectric effect in the corona, because visible glow was always found to be simultaneous with the beginning of ionization. Whitehead[1] has shown that there is ultraviolet light present in the corona glow at all stages. It might be supposed that before ionization, ultraviolet light is emitted by excited atoms. This might cause photoelectric emission of electrons from the metal surfaces, thus causing the corona deflections.

There are two possible ways of determining whether photoelectric action is the cause of corona; (a) to study photographically the intensity variation of the ultraviolet light emitted in various stages of the corona. (This is not a conclusive test, because the time interval between the emission of the first traces of light and the beginning of "corona" might be very small.) (b) To bring the critical intensity up to a point just below the critical value, and illuminate the tube with a strong source of ultraviolet light.

The test (b) was tried in air at atmospheric pressure for both polarities. The source of ultraviolet light, an iron arc, was held a few inches from the open end of the tube. The voltage was raised successively to within 200, 50 and 20 volts of the critical voltage, (about 12,000 volts). In each case no effect was produced by starting the arc. As there should have been abundant photoelectric emission at the brass cylinder, this suggests that the emission of ultraviolet light is a consequence and not a cause of corona. Whitehead[1] using x-rays as the ionizing agent also found that artificial ionization produced no change in the critical intensity.

Nevertheless, a spectroscopic investigation of the different stages of the corona glow might prove valuable. This might be conducted in two different ways: (a) by determining whether the different spectral lines appear in any definite order as the voltage is raised up to and beyond the critical value; and (b) by investigating the Stark effect at different points in space in the corona tube. The effect of a longitudinal magnetic field upon the critical intensity is also under investigation. The effect to be expected is a change in the speeds of the ions due to the spiraling around the wire, as in the case of the "magnetron" described by Hull.[14]

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TOKYO TO BUILD NEW ELECTRIC STATION

In order to provide for additional electric power to replace that formerly generated at the two stations of the Tokyo Municipality, located at Shibuya and Shinagawa, both of which were destroyed by the 1923 earthquake, the Tokyo City Office has decided to construct one large steam-driven electric-power generating station as soon as a suitable location can be procured.

The power generated will be utilized chiefly by the Tokyo street car system, but a certain amount will also be used for lighting service within the city limits.

Artificial Representation of Power Systems

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Synopsis.—The size and complexity of present day power systems have increased to the point where the prediction of the behavior of the system by analytical methods is more and more difficult. The solution of commercial networks by Kirchhoff's Laws or by cut and try methods, even with the help of star-delta transformations, leads to such involved equations that the need for simpler methods is keenly felt. Increasing attention has been given to various methods of representing power systems in miniature so that an experimental solution may be substituted for an algebraic one.

The d-c. short circuit calculating table is a satisfactory and relatively simple means of determining short circuit currents in networks, but is too inaccurate to give satisfactory solution under normal operating conditions.

An a-c. artificial representation of power networks in miniature has been developed by O. R. Schurig of the General Electric Company who used 3.75-kw. 110-volt three-phase generators as power stations. Actual transformers are used, while lines and loads are made up of conveniently arranged lumped units of inductance, capacity, and resistance. This apparatus has been in satisfactory operation for several years.

Evans and Bergvall of the Westinghouse Electric and Manufacturing Company used a test floor setup to check experimentally the theory of long line stability. Powers of about 500 kv-a. were used.

The present paper presents a method of artificial representation on a laboratory scale, decreasing the size of the apparatus and increasing the precision of the results.

All rotating apparatus has been eliminated. Generators are represented by phase shifting transformers; transformers by their equivalent circuits, and lines by lumped constants. A description of the apparatus used by the writers is presented, together with the results which were obtained by its use in the solution of several typical problems. An analytical check on one of the examples is given, showing a precision of better than 1 per cent.

Purpose and Summary

THE purpose of this paper is to describe briefly the work done by the authors under the direction of Dr. V. Bush, in the Research Laboratory of the Masschusetts Institute of Technology in designing, building, and testing apparatus for setting up miniature networks, using generating station powers of 100 watts or less. Complete voltage, current, and power solutions were made on several arbitrary networks. The representation was single-phase, using phase-shifting transformers for generating stations, and a vacuum tube voltmeter drawing absolutely negligible current for measuring potentials.

Introduction

Present power systems, comprising one to many generating stations, widely scattered loads, and the connecting lines, form complex electrical circuits. The problem of the power company is to supply its loads with dependable power at constant voltage in the most efficient way through these networks. To adequately solve this problem for an existing and constantly growing system requires thorough knowledge of its electrical characteristics. Lines and cables should be of proper size to carry present and reasonably anticipated future loads, and so placed that the minimum loss and interruption of service will occur. Future additions to lines and generating equipment should be so placed as to give the best system electrically, other conditions being equal.

What cable or line in the present system limits the load which may be added at a given point and what will be the voltage there with the new load? Where can a new feeder be placed to relieve the overload on a substation? How much may the load be shifted between stations within the system without overloading any feeder or causing excessive voltage drop? With a given load on the system, what distribution among the various generating stations gives the best voltage regulation, the minimum losses and best distribution of load over the various feeders? If a new tie line be put in, will it relieve or add to existing overload on the other lines under some conditions? The answer to these questions is found in numerous solutions of the network under normal steady state operation.

Another group of problems is presented when unusual conditions, such as short circuits, occur. Knowledge of what happens with short circuit at various points in a system is important. The proper size of current-limiting reactors must be determined to limit short-circuit currents to safe values. The magnitude of the currents again determines how much time may be allowed for relays to act without causing serious damage, and what size oil circuit breakers are required. As bus bars and other structural parts of the system have the severest mechanical stresses set up under short circuit, knowledge of short-circuit currents gives data needed in their design. Another factor is the voltage at critical points on the system, such as between generating stations, which has direct effect upon the ability of these stations to stay in synchronism. The current and voltage solution of the network under short-circuit conditions gives data from which the answer to the above problems may be obtained.

Methods of Solution

In general, the solution of a network under either normal operating or short-circuit conditions may be done analytically or by one of several experimental methods.

An analytical solution may be accomplished by using Kirchhoff's Laws, or, commonly easier on any but the simplest systems, the cut and try method. Using the former, equating the sum of all the currents entering a junction, and the sum of all voltages around any closed loop, each to zero, gives simultaneous equations, the

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To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 9-12, 1925.

solution of which solves the network. The method becomes so tedious and complicated in a network of any complexity that the cut and try solution is quicker and simpler. By this method, a voltage is assumed at the load most remote from a generating station. Knowing the kv-a. and power factor drawn, the current is calculated, and the drop due to it, over the line to the next load, added to the assumed voltage. This load current may then be found, the drop due to both currents in the next section of line added to obtain the next junction voltage, and so on until the generating station is reached. The discrepancy between this voltage, and that known to exist at the generating station, is used in making a new trial voltage assumption at the first load, and the problem worked through again. This procedure is continued until a sufficiently close check is obtained for the work in hand. Even the cut and try procedure is very laborious for other than comparatively simple networks and attention has been turned toward experimental solutions.

The most extensively used of these methods is the d-c. short-circuit table,[1] which serves a very useful purpose in giving approximate short-circuit currents. Its results are sufficiently accurate to be used in designing current-limiting reactors, oil circuit breakers, bus bars, and in setting relays. Two methods of representing the a-c. constants on the d-c. miniature are used; the resistance of the arms may be set equal to the reactance or impedance of the corresponding arm in the actual circuit. The former, or reactance method, is most frequently used and gives results less than 20 per cent and usually under 10 per cent in error when the generator reactance forms a large fraction of the total circuit impedance, and the power factor angle of the external circuit is roughly over 45 deg. Here the experimental currents are too large. The impedance method gives approximately the same error when used on circuits having a smaller power factor angle, but the currents found are below the true values.

This accuracy is good enough for abnormal conditions on a network where other factors, such as generator voltage, are so uncertain. For steady state solution, where results within 1 per cent or less are desirable, the d-c. solution is powerless, and alternating currents with true impedances must be used.

In a-c. representation, the metering of the circuit determines the scale of representation, which should, for convenience and economy, be as small as is consistent with the desired accuracy. Mr. Schurig finds that with standard portable instruments, the current must be 5 or 10 amperes with 200 or 100 volts respectively to keep errors safely below 10 per cent.[2] These errors are a result of the relatively large current taken by standard dynamometer instruments. The voltmeter and wattmeter potential coils together introduce about 1.6 per cent error in the current on the 5-ampere representation. With a line drop of 10 per cent the current coils of ammeter and wattmeter cause an error of slightly over 10 per cent in this drop at 5 amperes if uncorrected. The series impedances of these instruments may, of course, be substituted for an equivalent amount of line impedance, eliminating this error entirely. Error due to potential coil admittances cannot be thus eliminated.

Mr. Schurig's apparatus, in use since 1919, gives results which are usually within 5 per cent of the true value. The error is due to unsteadiness of such small machines and to the difficulty of making the large number of simultaneous readings required, with greater accuracy.

This apparatus may be used for obtaining normal steady state solutions, usually made single-phase; or for short circuits, either three-phase, one wire to ground, or between two wires, in which case unbalance due to unsymmetrical short circuit can be studied.

This, with the work of Evans and Bergvall[3], represents practically all the work done up to the present time. It was in the attempt to get a simple, compact, accurate, easily manipulated laboratory scale means of solving networks that the present method was worked out. Since the factor limiting the reduction of scale was metering equipment, principally the voltmeters, a currentless voltmeter would largely solve the problem. In Appendix I is described the vacuum-tube instrument developed to fulfill this requirement. As constructed, it has the accuracy of the standard portable a-c. voltmeter.

With this instrument available, it was found practicable to reduce generating station capacities to a maximum of about 100 watts.

The apparatus used consisted of phase-shifting transformers representing generating stations, smooth artificial lines, resistance loads and metering equipment.

The phase shifters have the same external characteristics as generating stations, which will later be demonstrated. They alter their load by changing the phase of their terminal voltage relative to the system, the phase shift being manually adjusted in the miniature, and by the torque supplied to the generator in the actual machine.

Sections of the smooth single-phase artificial line in the research laboratory, representing No. 00 B & S solid copper at 8 ft. 9 in. spacing were used for all the lines. In some cases, two parallel circuits were used to give additional capacity. Slide wires, giving adjustable unity power factor impedance, in series with the ammeter impedance or its equivalent, served as loads.

Voltage as high as 200 r. m. s. could be used and a maximum current of one ampere. Since the ratio of voltage to current is usually of this order of magnitude on the high-tension lines, actual line constants can be used, making current and voltage scales equal. The power scale will then be the product of the current and voltage scales.

1. For references see Bibliography.

The vacuum-tube voltmeter was used to measure all voltages, both in phase and magnitude, by the three-voltmeter method. Load ammeters were made a part of the load impedance. At the generating station, the terminal voltage was held constant on the line side of the wattmeter and ammeter current coils. Correcting the wattmeter reading for the small $I^2 r$ loss in the current coils, amounting to one per cent maximum, compensates for all meter errors in the circuit.

Advantages

a. *Apparatus.* All the component parts of this network, including generating stations, are portable, *i. e.*, one man can carry a phase shifter, the heaviest, piece of apparatus. No particular set-up is required before running the apparatus.

But little space is required, the total set-up of three generating stations, some 200 mi. of line, 6 loads and metering equipment requiring only 40 or 50 sq. ft. of table space.

Since the maximum current is an ampere, very small capacity of lines and loads is required, the smooth artificial lines having ample current capacity. Lamp cord is ample for leads. While the scale is small, ½ and 1 ampere ammeters work well and 1.5-amperes 150-volt wattmeters give satisfactory deflection. These are standard instruments.

Power requirements may not be of primary interest, still it is an advantage to have low energy consumption. The total input for three stations at full load is less than half a kilowatt.

b. *Operation.* The phase shifters can be set at phase angles unstable for synchronous apparatus and conditions will remain entirely steady. That is, any voltage at any phase within the range of the machines can be held indefinitely. The operator has far more control over the variables than in motor-generator sets.

With the absence of moving parts comes the steadiness of operation of a transformer. With steady supply voltage, the whole network remains free from current and voltage swings, which are somewhat bothersome in small rotating apparatus. Because of this steadiness and completeness of control, adjustments can be made easily, rapidly, and accurately. A network can be quickly solved. The time required for various tests, as will be shown, is surprisingly small.

Relative phases of all voltages are determined by the three-voltmeter method described later, and knowing the power factor of loads and generators, the phase of all currents can be found.

Since this system, as built, is all single-phase, unbalance cannot be studied either under normal operating conditions or in case of short circuit. It is limited to balanced polyphase or single-phase representation. A three-phase setup can, of course, be used to analyze unbalanced conditions. For steady state solutions this method combines laboratory precision with the simplicity of test floor procedure.

Artificial Generating Station

A power network consists essentially of generators, transformers, reactors, transmission lines of one sort or another, and loads. For a representation of power generation it is not necessary to duplicate all generators, for to an observer on the line outside a generating station, completely equipped with instruments, the number of units is undeterminable at any particular time. Also, if there is a Tirrill regulator on the high-tension side of sending end transformers, the presence of the transformers cannot be detected in normal operation. One requirement of an artificial generating station is that it must be able to maintain constant voltage at its terminals or some other point.

Let us see what happens when a generating station takes on or drops load, as viewed by this outside observer. Assume two identical power stations are supplying one load jointly over separate identical lines. Let the load voltage be the vector V_L and the current

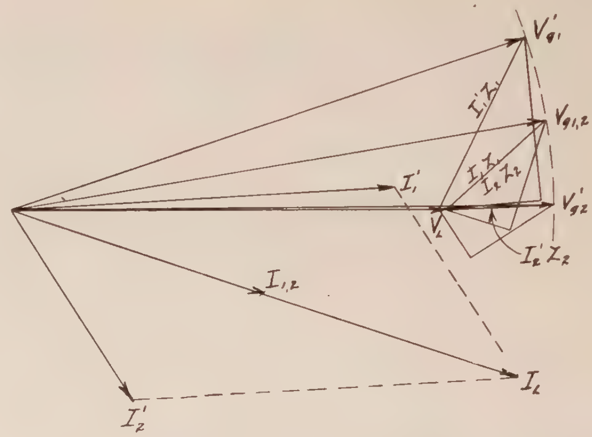

Fig. 1—Vetcor Diagram Showing the Effect of Shifting Load Between two Generators

taken by the load be I_L. See Fig. 1. The stations have identical governor settings so the load is divided equally. Adding the drops $I_1 Z_1$ and $I_2 Z_2$, where subscripts 1 and 2 refer to line and station 1 and 2 respectively, gives the station voltages, V_{g1} and V_{g2}, which are coincident and slightly advanced in phase from V_L, the load voltage.

Now let station 1 add 50 per cent to the load it is carrying and station 2 drop 50 per cent, the load current remaining constant in phase and magnitude and the station voltages being held constant in magnitude by the regulators. To get the new current I_1' over line 1 requires the drop $I_1' Z_1$. While the load component of I_1' is fixed by the power furnished the station by its prime mover, the reactive component is determined by holding the V_g constant. Imposing the above conditions requires that V_L be slightly decreased in the new condition. Neglecting this in its effect on load power, the vector diagram for the second condition becomes that shown by the primes in Fig. 1.

All that appears to the observer at the high-tension side of transformers at station 1 is a phase advance of V_{g1} when more steam was supplied to this station. The normal action of a station, then, is shifting the phase of a

constant voltage according to the power furnished the generators. A phase shifter therefore fulfills the entire requirements, provided sufficient power can be transformed to hold the voltage constant at the angles at which it is required. Output is a function of terminal-voltage phase relative to the system and a phase shifter output can be adjusted by varying the voltage phase and watching the wattmeter. By having taps at different points on the secondary, the magnitude of the voltage can be altered independently of the phase.

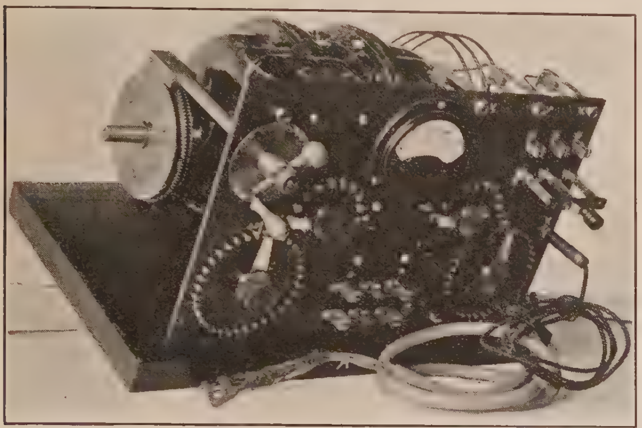

Fig. 2—Phase Shifter Complete

The input is through the three-phase cable in the foreground. Terminal voltage is adjusted by means of the switches on the panel. Voltage phase is adjusted by the crank on the upper left hand corner.

To operate these artificial stations, one must, of course, know the voltage regulator settings and turbine governor speed-load curve of the machines represented and this information is necessary for the operation of any artificial station.

The above discussion of generators applies to any synchronous apparatus so the phase shifter may be equally well used for synchronous condensers or loads at any power factor desired.

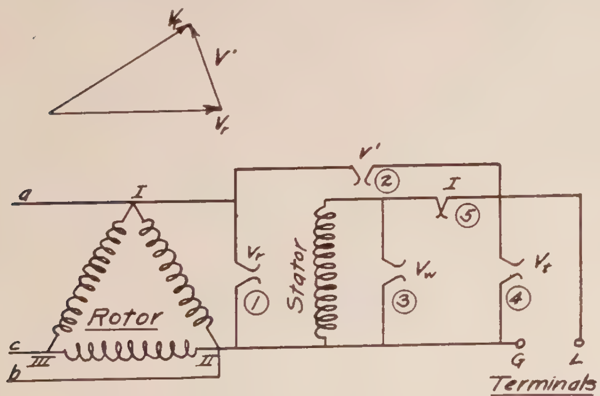

Fig. 3—Schematic Diagram of Phase Shifter Connections Showing Metering Jacks

The vector diagram illustrates the three-voltmeter method of determining voltage phase.

Phase Shifters

On the basis of the above reasoning, a phase shifter, of suitable capacity to fit well with the artificial lines, was designed and two machines have been built. They are three-phase rotor, single-phase stator machines wound on half h. p. induction-motor frames. The details are very similar to an induction regulator, adapted to the voltage and current used.

Fig. 2 is a picture of the complete artificial generating station while Fig. 3 gives a schematic diagram of connections including the metering system. V_r is a voltage jack connected across one phase of the supply voltage, which is used as a phase reference. V_t gives the voltage at the machine terminals G and L. V_w supplies the wattmeter potential coils and at I the ammeter and wattmeter current coils are connected in series. Since one connection of rotor and stator is common, V' will give the third side of the voltage triangle as indicated in the vector diagram. This gives the terminal voltage phase and magnitude. By carrying the common connection throughout the entire setup, the phase of all voltages can be determined.

Steady State Problems of the Power System and Their Solution on the Artificial Network

The division of load among alternators operating in parallel is determined, in the steady state, by the governor settings of the prime movers to which they are coupled. Thus if two turbines have the characteristics shown in Fig. 4, the division of load between them would be completely determined in advance. It is not customary, however, to regard the governor setting as fixed, but to alter the spring tension so as to make the units pick up or drop load at the will of the load dispatcher. The effect of so increasing the spring tension is to translate the characteristic of the unit upward so that the load carried at any given frequency is increased. On the basis of these considerations, the apparatus described in the preceding section was used to attack some of the problems which arise in the steady state operation of power systems. Several networks were set up on the artificial system, five of which are described. The first is made simple so that an analytical solution is practicable; the others are more complex and approach more closely the problems which are continually encountered in operation practise.

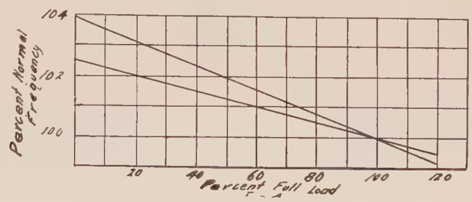

Fig. 4

Example 1. The first system set up for study in miniature consisted of two generating stations connected by 96 mi. of line. It was assumed that the generators were subject to the control of Tirrill regulators connected through potential transformers to the high-tension bus of the station, or so compounded as to compensate for the drop in the power transformers. It was also assumed that one station was clock governed so that the frequency was held constant by that station

at all loads, the other station delivering full load constantly to the system.

In solving the problem on the artificial network, the magnitude of the nominal system voltage, reduced by the scale of 1 to 707, was set at the phase shifter terminals and the phase adjusted until the stations were together. Conductance was then added at the point of load until the power absorbed corresponded to the desired value. Finally, the relative position of the phase-shifter rotors was adjusted until the stations delivered load in accordance with the original assumptions. That is, one station should deliver full load and the other station take the balance. The results of this solution are shown in Table I and the experimental results are compared with results obtained by standard cut and try methods.

TABLE I
LOADS ARE IN KW. $\times 10^3$

Load	P_A			P_B		
	Meas.	Calc.	Error	Meas.	Calc.	Error
65	74.9	73.4	2.04 per cent	− 3	0	....
85	74.9	75.2	0.39 per cent	20.4	20.0	0 per cent
103	74.9	74.9	0 per cent	38.3	38.4	0.26 per cent
118.9	74.9	75.0	0.13 per cent	58.6	59.5	0.11 per cent

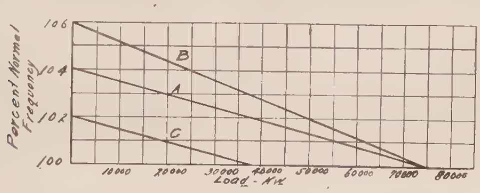

FIG. 5

The entire time required for the solution of this problem on the artificial network was less than two hours including the time required for setting up the apparatus and applying the instrument calibrations. When the results were checked analytically, it was found that an hour was required for each point checked, although the writers knew in advance about what the answers should be.

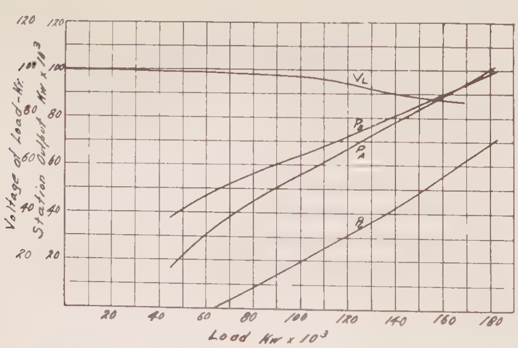

FIG. 6

Example 2. The second system studied on the artificial network consisted of three generating stations connected by lines, each 48 mi. long, to a load at the common junction. In this problem, as in the preceding one, it was assumed that the voltage was held constant at the high-tension side of the generating station transformer bank. The assumption in regard to governing, however, was considerably changed, the characteristics of the stations being assumed to be as shown in Fig. 5. The method of solution is identical with that used in the first example and about two hours and a half were required to obtain the results which are plotted in Fig. 6.

The characteristics which were assumed for the stations in this example must be based on the assumption that each station consists of one unit and one only, or else that all of the units of the stations operate all of the time. The addition of a unit in a station would have the effect of raising the frequency and would produce a discontinuous characteristic instead of the smooth curves of Fig. 5. The third example contains the added assumptions, in regard to the equipment of the stations and the order of putting the units into service, that are necessary to make the problem complete.

TABLE II

Station	Unit	Governor Sensitivity
A	15,000 kw.	2.0 per cent
A	30,000	3.0 per cent
A	30,000	3.0 per cent
B	37,500	2.5 per cent
B	37,500	2.5 per cent
C	22,500	2.0 per cent
C	22,500	2.0 per cent
C	22,500	2.0 per cent
C	45,000	5.0 per cent

Example 3. The configuration of the system of this example was taken as identical with that of Example 2, but with the additional assumption that the stations were to have the equipment shown in Table II and that the various units of the stations would be put into service in the sequence shown in Table III. In Table II the quantitative measure of governor sensitivity is the per cent regulation in frequency as the alternator goes from no load to full load. From these tables the station load-frequency curves shown in Fig. 7 were plotted.

TABLE III

Station		Machines in Operation	
A		15,000	
A	15,000	30,000	
A	30,000	30,000	
A	30,000	30,000	15,000
B		37,500	
B	37,500	37,500	
C		22,500	
C	22,500	22,500	
C	22,500	45,000	
C	22,500	45,000	22,500
C	22,500	22,500	45,000

The load voltages and outputs of the stations were measured for various values of load, but the results have not been plotted, since the discontinuity of the variables would render the curves meaningless. The results,

which were obtained in approximately two hours, are presented in Table IV.

Example 4. The purpose of this problem was to discover what time would be required to set up and solve the sort of problem which arises in determining the expansion policy of a power system. A certain power company was assumed to sell large blocks of power from

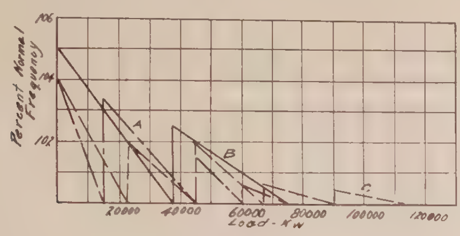

FIG. 7

its two stations A and B of Fig. 8 to the public utility corporations of two cities, L_1 and L_2. It is proposed to extend the system by building a line from J, to carry the load of L_3, a third city. The lines are all of No. 00 solid copper spaced at the corners of an 8-ft. 9-in.-equilateral triangle. L_1 and L_2 draw 93,500 kw. and 96,500 kw. respectively. The nominal system voltage is 100

TABLE IV
LOADS ARE IN KW. × 10^3. VOLTAGES IN KV.

Load	V	P_A	P_B	P_C
42.9	98.6	10.9	24.1	13.5
83.4	97.5	47.5	57.6	32.5
121.9	95.4	44.5	74.8	44.6
141.2	94.1	71.8	71.8	63.2
175.0	91.5	69.0	70.2	85.6
198.9	90.2	71.8	71.8	105.8
218.0	90.2	74.9	74.9	112.1
230.0	87.6	80.4	74.5	122.0

kv. and is maintained constant at the stations. The supplying company wishes to know what load can be supplied to L_3 without causing the voltage at any point on the system to drop more than 15 per cent from the nominal value. The division of the total load between the stations is also desired.

The solution of this problem by cut and try methods

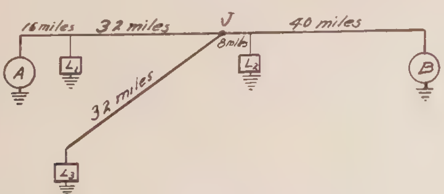

FIG. 8

is quite possible but it would require a considerable amount of time to get the correct answer. The solution of the artificial network required 45 min. of experimental work including the time required for making the set-up, and half an hour to apply the instrument calibrations and work up the data. The results show that 22,750 kw. can be delivered to L_3 and that when this load is being drawn, the other loads being as specified, stations A and B will supply 112,500 kw. and 96,500 kw. respectively.

None of the four problems which have so far been described has approached in complexity the problems which are constantly arising in commercial power networks. In such systems the problem of load dispatching, as well as the problems of voltage distribution which have been considered for the simpler cases, becomes increasingly important and difficult. The example which follows was laid out to determine whether the

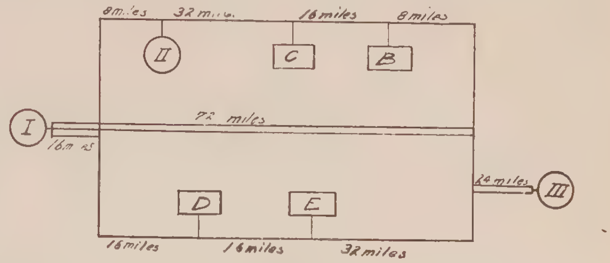

FIG. 9

artificial network could be used as a source of information to aid the load dispatcher in the operation of the system.

Example 5. The circuit of Fig. 9 represents the high-tension network of a typical power system. Generating stations are located at I, II, and III; A, B, C, D, and E represent substations located at load centers which were assumed to have the characteristics which follow. A supplies a large steel mill, a portion of which operates on a 24-hr. day; B carries the load of several large industrial plants; C an industrial load with a small lighting load in addition; E the industrial load of a small

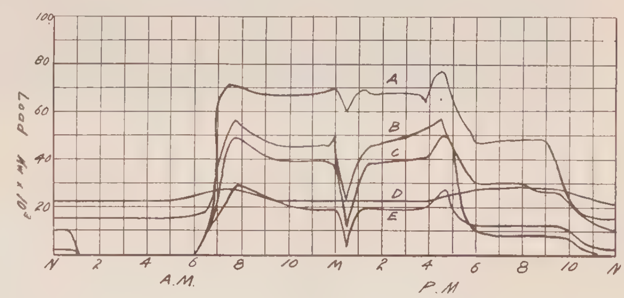

FIG. 10

town together with its lighting requirements; and D was assumed to supply a very large paper mill in a relatively small community where a small lighting load would be superimposed on the constant power demands of paper manufacture. The load cycles of these substations are plotted in Fig. 10. The problem is to determine the load distribution, during the four-thirty afternoon peak, which will give the minimum departure from the nominal system voltage at the various load centers; to determine the divisions of load at ten-thirty in the forenoon which will be satisfactory from the point of view of voltage regulation; and finally, to determine the distribution of load, as dictated by voltage maintenance, which can be used during the noon valley.

The illustration, Fig. 11, gives a general idea of the apparatus as set up for this problem, and shows the two phase shifters representing Stations I and II; between them is the vacuum-tube voltmeter.

For convenience, but one ammeter was used to measure the load currents, the equivalent impedance of the ammeter being inserted in series with the conductance, except when a reading was being taken. This made it possible to insert the instrument at will without disturbing the system. The solution of the problem, which required three hours, is given in Table V.

The A-C. Calculating Table

The work described in the foregoing section was done on smooth lines. There is no reason, however, why lines with lumped constants cannot be used in an artificial network and this network set up as an a-c. calculating table. There are two uses to which such a table might be put; it might be used by a power company in obtaining information to aid the load dispatcher, or it might be used by the consulting engineer in the solution of difficult steady state problems for his client.

In the first application the lines should be represented by lumped constant circuits. The nominal π method of representation[1] leads to an error of only 0.7 per cent with lines up to 200 mi. long, which makes this method entirely satisfactory. Transformers should be represented by their equivalent circuits; and if the assumption is made that the charging current of the line and the exciting current of the transformer produce a negligible drop in the transformer windings, it is possible to add the equivalent impedance of the transformer directly to the architrave impedance of the line or cable and the no-load admittance of the transformer to the pillar admittance. This will make the network much more compact without appreciably sacrificing the accuracy of representation.

The artificial lines and the equivalent circuits of transformers in a calculating table for the consulting engineer's use would be better designed with adjustable constants. In designing coils to represent the impedance of lines in a table of this sort, it would be well to make them up in units of five loop-miles with taps taken out of the coils to take care of the shorter sections. The resistance of the coil would be determined by the largest conductor of the lines to be represented, the inductance by the largest spacing. Thus two coils wound with 235 turns of No. 14 wire on an inside diameter of one and three-fourths inches (4.45 cm.) and one inch (2.54 cm.) thick, axially, would represent five loop-miles (8.04 loop-km.) of any line with a conductor not larger than No. 0000 and a spacing of less than 25 ft. (7.65 m.); an adjustable resistor in series with the coil takes care of the higher resistance of the smaller conductor sizes.

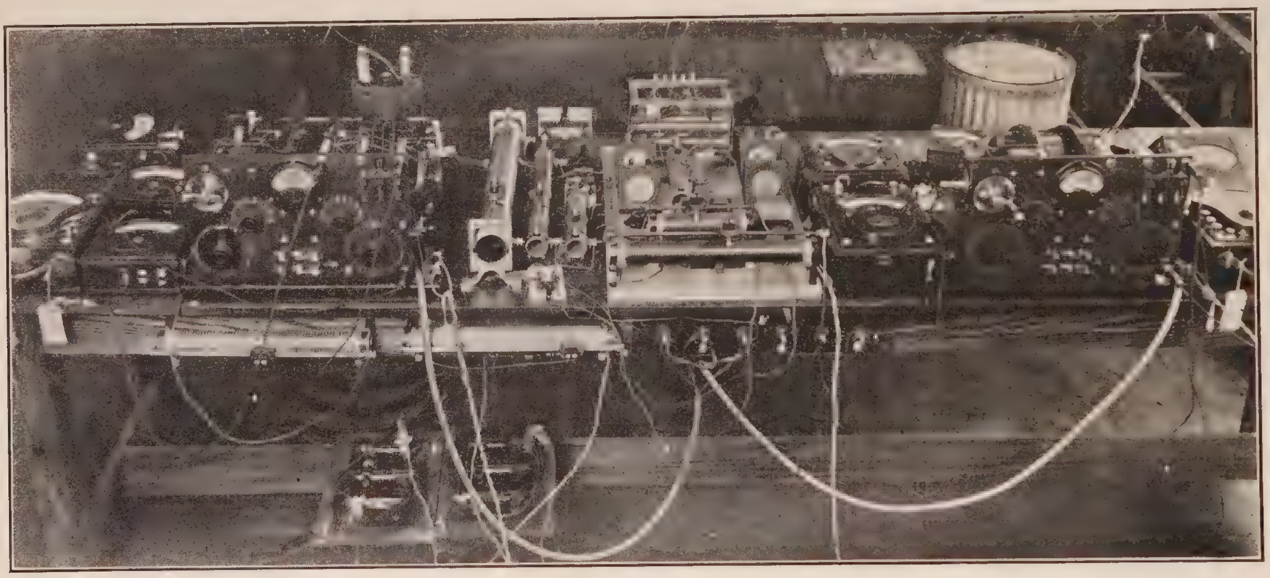

Fig. 11

Loads on the calculating table would be represented by admittances. They should be made up in boxes with point switches calibrated directly in real and quadrature mhos. Then from the voltage it would be possible to set at once the admittance to give the desired power at any power-factor without the aid of any meter except the vacuum-tube voltmeter which would not draw power to introduce an error.

In conclusion, the writers wish to express their appreciation of the kindness of C. R. Oliver, of the New England Power Company, in supplying data on an actual power system.

Appendix I

The Thermionic-Tube Voltmeter

The problem of making measurements on artificial lines does not find its solution in the use of ordinary instruments. This is especially true in the case of the voltmeter as a consideration of the scale adopted will show. For example, in the work described in this paper

1. A. E. Kennelly, "Artificial Electric Lines."

the voltage scale was such that 100 volts on the miniature system corresponded to 70,700 volts on the system represented and, since there is no change in the impedances, one watt on the miniature represents 500 kw. single-phase or 1500 kw. three-phase on the actual system.

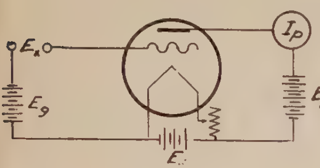

FIG. 12

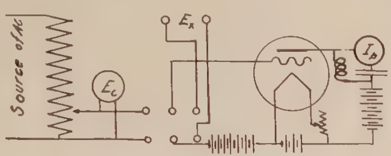

FIG. 13

The ordinary dynamometer type voltmeter takes approximately 0.660 amperes at full scale. This means, for a 150-volt meter, 9 volt-amperes at full scale; or at 141.4 volts, corresponding to 100 kv. in the above scale, 7.96 volt-amperes which is equivalent to 11,920 kv-a. three-phase. The remedy is an instrument which, like the electrostatic voltmeter, will draw no current, but stant filament temperature as the resistance of the filament of the tube increases with age.

In order to obviate these difficulties, a double throw switch was placed in the grid circuit so that the grid could be thrown over to a calibrating voltage immediately after each reading. The drawing, Fig. 13, shows how this was done. The voltages were impressed across the ends of a high resistance drop wire (2.12 megohms) and the filament and grid were placed across a portion of this wire, thus increasing the range of the instrument. The plate current of the vacuum tube consists of an alternating current superimposed on a direct current. The use of a d-c. milliammeter in this part of the circuit is impossible as it would read only the average current, the d-c. component. An a-c. milliammeter or thermo-couple instrument would be satisfactory, except that the change in alternating current is small compared to the steady d-c. component, so that the accuracy would be poor. To eliminate this trouble a 2 μf condenser was placed in series with the meter to

TABLE V

V_A	V_B	V_C	V_D	V_E	P_I	P_{II}	P_{III}	Hour
94.1	95.6	91.1	95.4	93.5	115.0	69.5	76.0	4:30 P. M.
95.9	94.9	94.3	97.0	96.0	112.0	74.8	27.9	10:30 A. M.
97.7	95.6	94.6	97.6	96.5	56.6	74.0	75.2	10:30 A. M.
97.4	95.6	95.5	97.6	93.0	111.5	22.6	74.9	10:30 A. M.
98.5	97.8	98.2	98.2	98.5	111.4	..	24.1	12:30 P. M.
97.8	97.2	96.9	98.0	98.0	59.1	74.8	..	12:30 P. M.

P_A	P_B	P_C	P_D	P_E	Hour
76.0	56.6	49.2	22.9	23.0	4:30 P. M.
67.2	45.7	38.1	18.5	22.5	10:30 A. M.
67.5	45.7	38.0	18.5	22.5	10:30 A. M.
67.1	45.7	38.1	18.5	22.5	10:30 A. M.
61.2	22.5	9.9	2.1	22.5	12:30 P. M.
61.2	22.4	9.9	2.1	22.6	12:30 P. M.

which will have the accuracy of a meter of the galvanometer type.

The vacuum tube operating as a repeater will draw no current from the input circuit so long as the grid is maintained at a negative potential with respect to the filament. This makes it possible to vary the plate current of the tube by impressing a voltage between the filament and the grid without disturbing the circuit impressing the voltage. The simplest way of doing this is shown in Fig. 12. The plate milliameter is calibrated in volts impressed.

In a circuit of this kind there are several difficulties. The alternating voltage must not reach a maximum value greater than the value of the grid bias; the grid bias must not be so great as to approach the cut-off point of the tube; and all the parameters of the circuit, as filament temperature, grid bias, and plate voltage, must be held absolutely constant. The most difficult of these problems is the maintenance of constant filament temperature. It is even difficult to hold the filament voltage sufficiently constant for work of this sort, and constant filament voltage does not mean con-

block out the direct current and an inductance of 39 henries was connected across the instrument and condenser to bypass this component.

The circuit of Fig. 13 was mounted together and made self-contained, with the exception of the batteries and some of the rheostats. The method of continuous calibration makes the precision of the vacuum-tube instrument the same as that of the voltmeter which was used in calbration. No difficulty was encountered in manipulation after the circuit was set up; as many as 120 readings being taken in an hour with ease.

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Squirrel-Cage Induction-Motor Core Losses

BY T. SPOONER[1]

Member, A. I. E. E.

Synopsis.—An experimental method is presented for segregating the various no-load losses of a squirrel-cage induction motor. It is shown that for insulated rotor bars the losses consist principally of stator fundamental-frequency losses, rotor surface losses and eddy-current losses in the rotor bars due to radial and tangential slot-leakage fluxes in the rotor slots caused by reluctance pulsations in the air gap between stator and rotor teeth. The pulsation losses vary about as the square of the air-gap induction and about as the 1.2 power of the frequency. The surface losses for the particular slots described are from ¼ to 1/3 of the total pulsation losses. The pulsation losses are approximately the same whether or not the rotor bars are connected by end rings, and are approximately equal to the stator fundamental-frequency losses.

Introduction

In a recent edition of Behrend's "The Induction Motor," it is stated that certain assumptions with reference to induction-motor core losses are "justifiable only on account of a profound ignorance of the causes of core losses and the magnitude of these losses." This may be true to a degree in connection with the core losses of this type of machine, particularly concerning the high-frequency pulsation losses due to the pulsations in the tooth flux as the rotor teeth pass by the stator teeth. Some experimental work has been done to segregate these high-frequency losses for wound-rotor induction motors, but so far as we know no data have been published showing a segregation of the various types of core loss for squirrel-cage induction motors. In this paper we propose to give such data for a special experimental machine.

Types of Core Loss

Squirrel-cage induction-motor no-load core losses may be classified as follows:

1. Fundamental-Frequency Losses
   - a. *Stator*
     1. Yoke hysteresis
     2. Yoke eddy current
     3. Tooth hysteresis
     4. Tooth eddy current
   - b. *Rotor*
     1. Core hysteresis (Slip frequency)
     2. Core eddy current (Slip frequency)
     3. Tooth hysteresis " "
     4. Tooth eddy current " "
2. High-Frequency Pulsation Losses
   - a. *Stator*
     1. Surface
     2. Tooth pulsation
     3. Copper eddy current
   - b. *Rotor*
     1. Surface
     2. Tooth pulsation
     3. Rotor bar eddy current
     4. High-frequency damping current in secondary winding.

In the squirrel-cage construction some of these losses will be negligible. For instance, there will be no appreciable fundamental-frequency losses in the rotor under ordinary no-load conditions due to the very small slip. High-frequency damping currents in the rotor bars may exist not only to damp out the tooth pulsations but also to give more nearly a sine-wave distribution of flux in the air gap. The value of these latter currents will depend upon the number of slots and type of stator winding used. The relative magnitude of these various losses will be discussed later in connection with the test results.

Test Apparatus

The induction motor used in this investigation was a special 3-phase 4-pole 60-cycle 440-volt machine of about 35-h. p. capacity. The stator and rotor punchings had the following dimensions:

Stator

Punchings O. D. 19 in. I. D. 13-19/32 in.
Length 6 inches
No. Slots (open) 60
Air gap 0.047 in.

Rotor

Punchings O. D. 13½ in. I. D. 4 in.
Length 6 inches
No. Slots (nearly closed) 78
See Fig. 1 for slot dimensions
The rotor bars were 0.484 in. by 0.3 in. by 9.25 in.

The rotor was direct-connected to a 3-h. p. d-c. motor, the set being supplied with 3 ball bearings. The induction-motor, stator and rotor punchings were made of enameled 0.0172 in. one per cent silicon sheet steel. Special pains were taken to remove the burs before enameling the punchings. The induction-motor stator was supplied from a 440-volt 3-phase generator direct-connected to a d-c. drive motor, the set having a considerably larger capacity than the special motor under test. The d-c. motor of the special set was supplied from a storage battery.

Test Methods

Three sets of tests were made: (1) with no windings on the rotor, (2) with rotor bars in position but no end rings, (3) squirrel-cage winding complete with brass end rings. In order to eliminate the uncertain variations due to laminations being short-circuited by the rotor bars, as is the condition for the standard construction, slightly smaller bars than normal were used and insulated by means of 3-mil fish paper.

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To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 9-12, 1925.

For the first two tests the results were obtained by the method described in the appendix of a previous paper.[1] The method consisted in measuring the a-c. input to the induction-motor stator and the d-c. input to the drive motor, subtracting the friction and windage, brush and $I^2 R$ losses from the inputs and plotting the curves as indicated by Fig. 2 for a given a-c. voltage and frequency and various rotor speeds. a, b, c, d, e, is the a-c. input and o, f, g, h, i, is the corresponding d-c. input. c is the midpoint of b, d, and g is the midpoint of h, f. $O - c'$ is the stator fundamental-frequency loss for the given conditions.

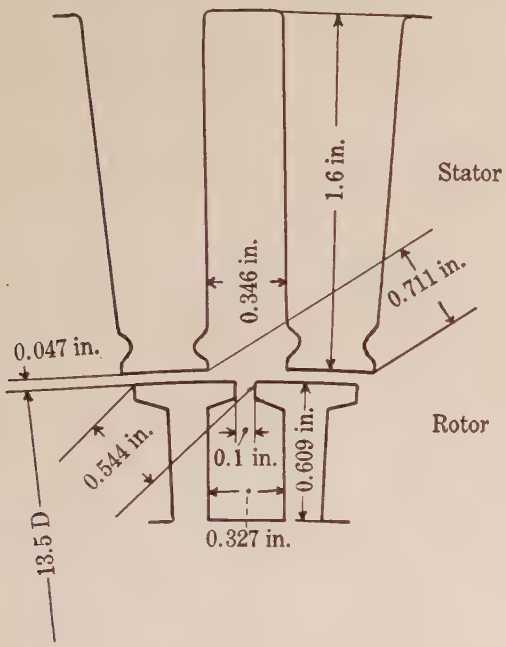

Fig. 1—Dimensions of Stator and Rotor Punchings

$O - g'$ is the high-frequency pulsation loss. O, g, j, is the pulsation-loss curve for various rotor speeds and the given applied stator frequency and voltage. For a theoretical discussion of this method see Alger and Eksergian.[2]

Due to voltage limitations of the supply generator an average air-gap induction of 22 kilolines per sq. in. only was obtainable by this method. In order to extend the range direct current was applied to the stator and the input to the drive motor noted for various speeds and stator fields, as described in the previously-mentioned paper on Surface Losses. The fundamental-frequency rotor losses as obtained from the test with alternating current on the stator were extrapolated and subtracted from the total, giving the pulsation losses. Results up to 32 kilolines, air-gap induction, were obtained.

For the third set of tests with the complete squirrel-cage winding we had to resort to a slightly different method of procedure. Due to the large torque produced by the rotor windings, speeds only slightly different from synchronism could be used. Therefore tests were made with rotor speeds varying in general not more than 0.2 of a cycle from synchronism. Two points above synchronism and two below were measured

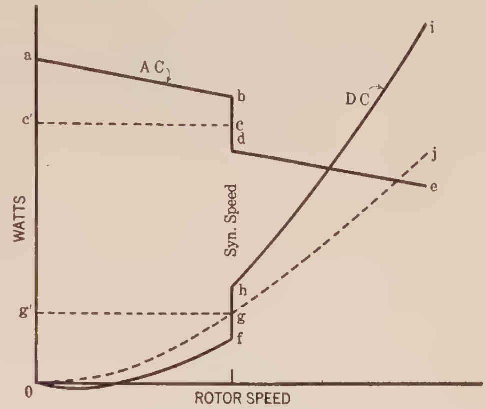

Fig. 2—Inputs to Motor-Generator Set, Showing Method of Segregating Losses

and the results plotted as indicated by the typical results of Fig. 3. It will be noted that even for the very slight departure from synchronism of 0.1 of a cycle, the inputs and outputs are considerable. The very greatest care was necessary in measuring these

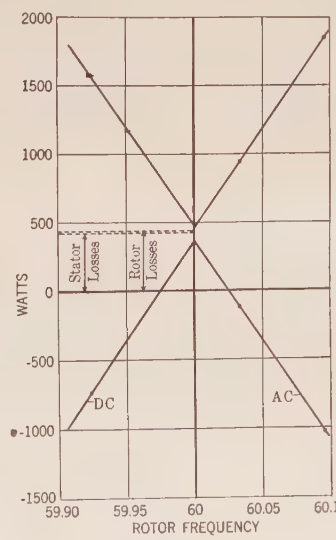

Fig. 3—A-C. and D-C. Inputs to Motor-Generator Set With Suqirrel Cage Rotor 60 Cycles

inputs and outputs in order to obtain reliable results, and without a very steady d-c. and a-c. supply such tests are impossible. Three synchronous speeds were used, namely, 20 cycles, 40 cycles and 60 cycles, and as wide a range of voltages as possible. It may be noted that with the scale of abscissas used for Fig. 2 the lines for Fig. 3 would be nearly vertical.

1. Surface Iron Losses with Reference to Laminated Materials, by T. Spooner and I. F. Kinnard, presented before the A. I. E. E. in Philadelphia, Feb., 1924.

2. Induction Motor Core Losses. Jour. A. I. E. E., Oct., 1920, p. 906.

In order to measure the slip frequency, use was made of a coil which was placed around a single rotor tooth for the purpose of measuring the tooth-flux pulsations. This was connected to a d-c. galvanometer through slip rings. Whenever the d-c. galvanometer completed a cycle of oscillation, the rotor completed a cycle of slip. The time was measured by means of a stop watch.

Test Results

Fig. 4 gives the pulsation losses for a synchronous frequency of 20 cycles and the three conditions,

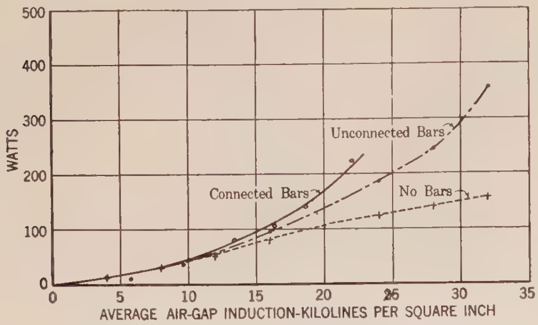

Fig. 4—Pulsation Losses—20 Cycles

namely, no rotor bars, bars unconnected and bars connected. With no bars it will be seen that the rate of increase of pulsation losses decreases for the higher air-gap inductions. This is due to saturation of the teeth and consequent reduction of the tooth pulsations as explained in a previous paper.[3] The difference between these results and the losses with the unconnected bars is due to high-frequency slot leakage fluxes caused by saturation of the teeth which produced eddy-current losses in the bars. These fluxes are

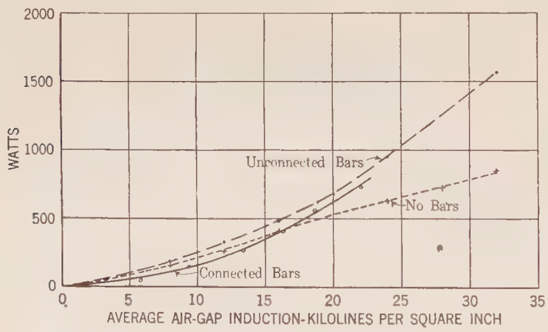

Fig. 5—Pulsation Losses—60 Cycles

both tangential and radial and while the density is only a few hundred lines per square inch, the frequency is so high that the losses become considerable.

With the bars connected, the high-frequency tooth pulsations produced currents in the bars which tended to damp out the tooth-pulsation fluxes. In fact, they do this so effectively that at 60 cycles no tooth-pulsation voltages could be detected by any a-c. indicator available when connected to the previously-mentioned coil surrounding a rotor tooth. With no rotor bars this voltage was of the order of 3 volts and with the bars connected was less than 0.1 volts. It will be noted that in spite of this damping out of the high-

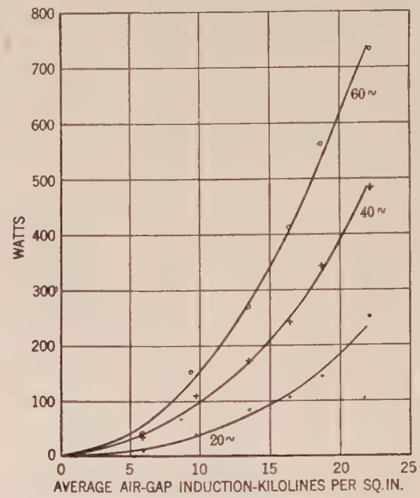

Fig. 6—Pulsation Losses—Insulated Bars Connected

frequency fluxes, the pulsation losses are not much changed. This will be discussed later.

Fig. 5 shows the corresponding 60-cycle pulsation losses. 40-cycle losses are intermediate.

Fig. 6 shows a comparison of the pulsation losses for

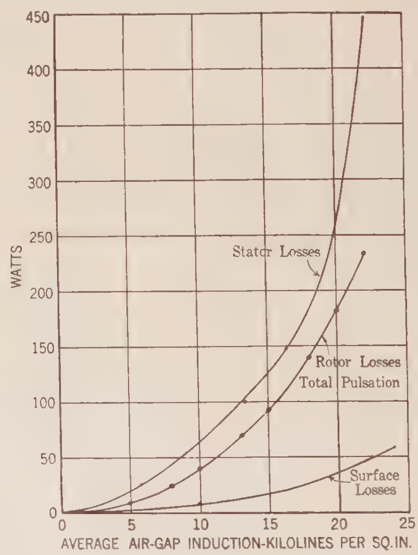

Fig. 7—Insulated Bars—Connected—20 Cycles

the three fundamental frequencies, 20, 40 and 60 cycles with the bars connected. It will be noted that in spite of the difficulties of test the points line up fairly well.

Fig. 7 shows the no-load losses for 20 cycles applied to the stator with the bars connected. It will be seen that the pulsation losses are nearly as great as the fundamental-frequency stator losses. These pulsa-

3. Tooth Pulsation in Rotating Machines, by T. Spooner. Jour. A. I. E. E., July, 1924, p. 646.

tion losses include the surface losses, which are given by the lower curve and were plotted from the results previously obtained on smooth core rotors.[1] Since the rotor slots are nearly closed, it is assumed as a first approximation that the surface losses for the rotor are the same as for a smooth-core rotor. Also due to the nearly closed rotor slots it is assumed that

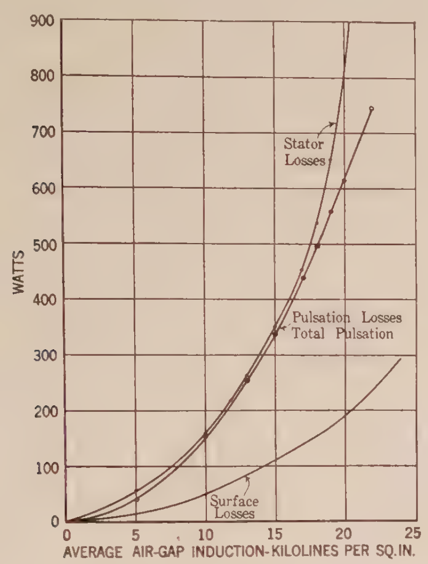

Fig. 8—Insulated Bars—Connected—60 Cycles

the stator tooth-pulsation and surface losses are negligible. The rapid increase of stator losses at high inductions is due to the fact that the stator yoke was rather narrow and began to saturate, thus forcing flux into the solid frame and hence rapidly increasing the stator losses.

Fig. 8 gives the motor core losses corresponding to an applied frequency of 60 cycles. The relative losses

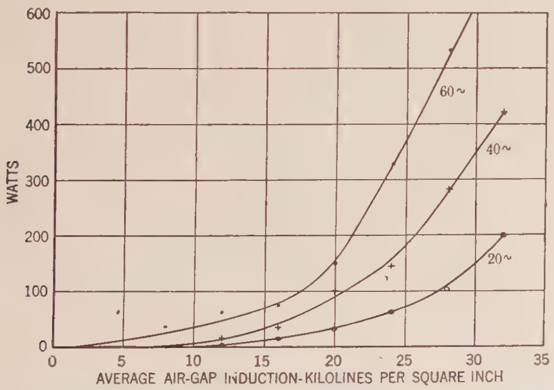

Fig. 9—Rotor Copper Eddy-Current Losses. Bars Insulated and not Connected

are much the same as for 20 cycles. The 40-cycle results lie in between the 20- and 60-cycle losses.

Fig. 9 gives the eddy-current losses in the unconnected copper bars as obtained by subtracting the test values of set No. 2 from set No. 1, namely, the difference between the losses with the unconnected bars and no bars.

Fig. 10 gives the stator losses with the connected bars and with no bars on the rotor. The increased losses in the former case should be noted.

Discussion of Results

The fundamental-frequency stator losses can be calculated in the ordinary way from the known fundamental magnetic characteristics of the material. If appreciable burrs are present or the enamel on the punchings is not in good condition, eddy losses will be

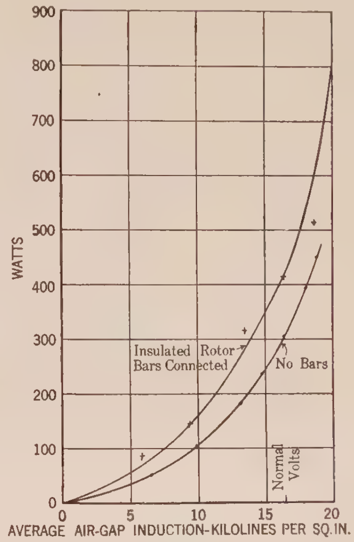

Fig. 10—Stator Losses—60 Cycles

present which are not subject to accurate calculation. Also, if it is desired to go to such a refinement, the additional losses in the yoke material due to the elliptical field may be calculated by the method developed by Alger & Eksergian.[2] This correction is fairly small in this case.

Since we are dealing only with synchronous speeds

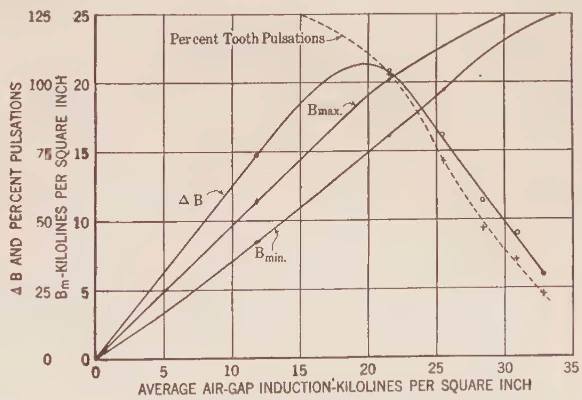

Fig. 11—Maximum Tooth Inductions (B Min.) and Tooth Pulsations

the rotor slip-frequency losses are zero. In any case they would be fairly small except under starting conditions. They may be calculated in the ordinary way for any desired slip.

As previously mentioned, for the nearly-closed slots

it is assumed that the stator surface and tooth-pulsation losses are negligible. We have left then only the rotor high-frequency losses. The method of calculating the surface losses has been described previously.

Referring now to the rotor tooth-pulsation losses, we shall give only brief attention to the condition with no rotor bars, since the losses do not correspond to working conditions though the results are of interest in connection with other types of machines having wound rotors. These tooth-pulsation losses are the result of high-frequency pulsations which penetrate the whole length of the rotor teeth and are caused by variations in the reluctance between the individual stator and rotor teeth at the air gap. The method of calculating these pulsations has been given previously.[3] The actual magnitude of the tooth pulsations was measured ballistically with direct current applied to the stator as shown by Fig. 11. The effect of saturation in reducing the flux pulsations should be particularly noted. Inductions are expressed in net section of iron and correspond to the position of maximum air-gap flux. Remembering that for a 60-cycle fundamental frequency the tooth pulsations have a frequency of 1800 cycles, it can easily be seen how these high-frequency fluxes produce the hysteresis and eddy losses which were observed. Referring to Figs. 4 and 5, the effect of saturation on the tooth-pulsation losses for no bars should be compared with the tooth-pulsation data of Fig. 11.

For the second case with the unconnected bars we have in addition to tooth-pulsation losses, eddy-current losses in the bars due to radial and tangential slot leakage fluxes. As the teeth begin to saturate, high-frequency flux pulsations pass down the rotor slots and produce eddy currents in the rotor bars. Also, when a rotor tooth is opposite a stator tooth and therefore in position of minimum air-gap reluctance, the adjacent teeth are in a position of greater air-gap reluctance, therefore at a lower magnetic potential. Due to the saturation of the first tooth flux crosses the air gaps to the teeth at lower magnetic potential, thus giving rise to tangential leakage fluxes of the same high frequency as the radial fluxes. When a tooth is in a position of maximum air-gap reluctance the tangential leakage fluxes flow in the opposite direction across the slots.

The magnitude of these slot-leakage fluxes was measured ballistically and found to be only from one to two hundred lines per square inch, even at fairly high tooth inductions. Nevertheless, due to the large section of the copper bars and high frequency, losses of several kilowatts would have been produced at the higher inductions with 60 cycles applied to the stator if there were no skin effect. Due, however, to skin effect, these eddy losses were much reduced, giving the values actually observed. The magnitude of these leakage fluxes can be calculated roughly from the permeability of the tooth material and the variations in tooth air-gap reluctance but the details will have to be reserved until a later date.

For the third case with the rotor bars connected we arrive at further complications. As it has been shown experimentally that the tooth pulsations are reduced to small values, it might at first be assumed that since the pulsation losses remain nearly the same, the high-frequency circulating currents in the copper bars give rise to losses which are approximately equal to the decreased iron losses in the teeth.

The magnitude of these high-frequency currents was calculated for an average air-gap induction of 22 kilolines and found to be about 100 root-mean-square amperes maximum. The corresponding losses were calculated using Field's Method[4] of calculating the effective resistance and it was found that this would account for only a comparatively small percentage of the observed losses. It was therefore concluded that these losses were the result of the eddy-current losses in the copper due to increased tangential slot-leakage fluxes, due to the increased magnetomotive force between adjacent bars. Since pulsating flux can no longer flow down the teeth to compensate for the varying tooth air-gap reluctance, a higher magnetomotive force exists between the adjacent teeth and as a consequence more leakage flux passes tangentially across the upper part of the slots, producing higher eddy losses than existed with the open-circuited rotor bars and thus compensating for the decreased iron losses in the teeth. Moreover, these tangential slot-leakage fluxes will be of considerable magnitude at lower tooth inductions since we would have the same effect produced by the short-circuited bars as would be produced by saturation of the teeth. The radial slot-leakage fluxes probably would not be greatly altered by the short-circuited bars.

The rate of increase of these losses with induction and frequency is interesting. As previously reported,[1] the surface losses increase about as the square of the air-gap induction and as the 1.5 power of the frequency. For the closed-bar rotor, the pulsation losses increase about as the square of the induction (a little less at the lower inductions and a little greater at the higher). The pulsation losses increase about as the 1.2 power of the frequency and if the surface losses are subtracted, the pulsation losses increase about as the first power of the frequency.

The increase in fundamental-frequency stator losses with closed rotor bars (Fig. 10) is probably due to the following cause. With no rotor bars the field form at the air gap is rather flat. In the presence of the squirrel-cage rotor at synchronous speed there is no fundamental frequency current in the rotor bars, but there are higher frequency currents which circulate and tend to give a sine wave distribution of flux in the air gap, thus increasing the maximum stator-tooth

4. A. B. Field, Proc. A. I. E. E., Vol. 24, 1905, p. 659.

inductions and probably accounting partly at least for the increased fundamental-frequency stator losses.

Conclusions

The important no-load losses for a squirrel-cage induction motor having open stator slots and nearly closed rotor slots are, then, the fundamental frequency stator hysteresis and eddy-current losses in the teeth and yoke. (These may be altered somewhat due to change in field form resulting from harmonic currents in the squirrel-cage winding). There are also, of course, $I^2 R$ losses in the stator windings due to the magnetizing current.

In the rotor we have surface losses, eddy losses in rotor bars due to tangential and radial slot leakage fluxes and $I^2 R$ losses in the rotor bars due to high-frequency damping currents. The varying magneto-motive force due to the air-gap tooth-reluctance pulsations produces tangential slot-leakage fluxes which give large eddy losses in the bars but under conditions of large skin effect, namely, the eddy currents are concentrated near the surface of the bars. There are also, of course, certain losses in the iron due to high-frequency leakage fluxes which can be estimated only very roughly.

When the rotor bars are not insulated from the core new conditions arise which we hope to consider at a later date. Uninsulated bars are, of course, the standard practise.

In conclusion we may say that for the ordinary squirrel-cage induction-motor the rotor pulsation losses are of the same order of magnitude as the stator fundamental-frequency losses and that the pulsation losses are approximately the same whether or not the rotor bars are connected.

A CONSTANT E. M. F. WITHOUT SLIDING CONTACTS

By Carl Hering

The French physicist, Poincare, some time ago announced a theorem to the effect that it is not possible to induce a constant e. m. f. by means of motion without the use of electric contacts sliding over circles of appreciable diameters. It is believed that this is generally accepted and taught as a universal law.

The two following cases seem to be exceptions, and if so, the law is not a universal one but only a special case law, and may therefore have misled us in closing to us possible fields of development.

A law used in classical mathematical physics states that a single magnetic pole would be propelled along a line of force. Hence such a pole would move along a circle, around a straight current-carrying conductor, and therefore, according to Lenz's law, which is believed to be a universal one, if it be forcibly moved around that circle in the opposite direction, it would generate a constant e. m. f. in the conductor; in fact, it must be generating a constant counter e. m. f. while moving as a motor.

In an ingenious experiment of Faraday, not known as well as it should be, this motor action is demonstrated. One pole of a straight bar magnet, placed inside of a breaker, was tied flexibly to the middle of the bottom. Enough mercury is added to float the magnet in an oblique upward position with its other pole projecting above the mercury. A current is then passed vertically through the mercury, entering by a vertical conductor inserted in the middle of the top surface of the mercury, and leaving by another through the middle of the bottom. The projecting pole will then move steadily and continuously in a circle along the lines of force encircling the upper conductor.

If now it is forced to move in the opposite direction, an e. m. f. must be generated according to Lenz's law, though Faraday does not seem to have noted this. As the magnet can be perfectly insulated, there are no sliding contacts in the electric circuit, though perhaps a forced and strained definition of one might be devised to force it to fit this case.

In the second case, a lot of short bar magnets, shorter than the inside radius of a vertical cylindrical jar, are suspended in a horizontal position radially between the center axis and the circumference of that jar, so that they can move around the axis of the jar, in a horizontal plane, like the spokes of a horizontal wheel, with like poles toward the center. If now the jar be filled with a liquid conductor, like an electrolyte or mercury, and a current be passed vertically through the liquid, Northrop showed that the magnets would move like the spokes of a revolving wheel, according to the law stated above. The present writer added that if forced to move in the opposite direction it would have to generate a current in the electric circuit according to Lenz's law. Again, the magnets may be insulated and there are no sliding contacts in the electric circuit. Incidentally, if the outside circuit of the jar be made entirely of an electrolyte, this would be (on paper at least) a method of generating a continuous current in an electroylte, without any electrodes.

It would require some juggling of Maxwell's law of induction to force it to fit these cases. Why not reframe such laws so as not to mislead the student, but rather to lead to new fields, and not burden him with strained and involved definitions of sliding contacts, which could be avoided.

LIFE TESTS OF INCANDESCENT LAMPS

Through misunderstanding, we published in the December Journal, under the above heading, a news item in regard to some lamp tests made by the Bureau of Standards "during the past month." These tests were made in May instead of November as indicated, and formed part of the Photometria Sections' work for the fiscal year ending on June 30, 1924.

Predicting Central Station Demand and Output

BY FARLEY C. RALSTON[1]
Member, A. I. E. E.

Synopsis.—For relatively long-term predictions of central station demand and output, of the order of one year or more, the use of constant (or approximately constant) yearly percentages of growth is common and well understood. This method is frequently applied by straight, or nearly straight, line projection of the plot of past data on semi-logarithmic paper.

When the term of the prediction is less than one year, or when detailed estimates are required throughout any year, this method fails on account of the seasonal variations.

In this paper is investigated the nature of the seasonal variations in the daily load curve of the company with which the author is connected, as they affect the output and the peak demand.

The variation of the kilowatt-hour output is first analyzed: and it is found that, in a year fairly free from abnormal business conditions, a plot of the "normal mid-week day" outputs on semi-logarithmic paper can well be rationalized to a curve whose components are an inclined straight line and a single-frequency sine curve.

This curve is represented analytically by the following equation:

$$y = J\,e^{kr}\,[\,1 + L\cos\,(0.986\,r - M\,)^{\circ}\,]$$

In this equation, e is the base of the natural system of logarithms: r, the number of days (positive or negative as the case may be) counted from a given zero date: and J, k, L and M are parameters to be determined for each curve.

Factors are included for determining the output on holidays, Sundays, Mondays and Saturdays, as compared with adjacent "normal" mid-week days.

For short-term peak demand predictions, the method employed is to separate into three components that portion of the daily load curve beginning at 2.30 P. M. and ending one and one-half hours after sunset.

These three components are a constant "base load," an "afternoon block" and an "evening block."

In the formula;

$$z = A\,F\,(t) + B\,f\,(t) + C$$

expressing this condition, the maximum value of the afternoon block is designated A, the maximum value of the evening block B, and the value of the base load C.

Both F (t) and f (t) are found to be exponentials in the data used and their forms are given with methods of evaluating the parameters.

However, even this stage having been reached, the formula is still in awkward shape for obtaining, analytically, the solution most often desired,—namely, the value of the peak demand and the time at which it will occur.

A graphical construction is, therefore, developed which solves simultaneously for these two quantities. This solution is equally valid if the form of F (t) and that of f (t) are defined only graphically, it is not necessary that their analytical expression should be known, nor even that they should be analytical in character.

* * * * *

FOR a variety of reasons, predicting future conditions is frequently necessary in most commercial enterprises. As regards the peak demand and output of central station companies, the forecasts required fall into two distinct classes.

Long Term Predictions

The first class extends usually from one year or thereabouts to a number of years in the future, admitting of latitude in the estimation of values increasing with the length of view.

The methods of making forecasts of this class are quite simple and well understood, and will not be discussed here in detail.

It should be stated that the material of this paper is almost entirely taken from the records of the company with which the author has been connected for some time; but such data from other companies as has been available support the view that the theory developed is of very general application.

In the case of the company mentioned, and in most others, it is found that, taken over a number of years, the growth of the yearly kilowatt-hour output and the maximum yearly peak approximates very closely to a constant yearly percentage increase. For this type of load growth, plotting on semi-logarithmic paper is particularly suitable, since the plot then approximates to a straight line.

To estimate the growth for any period in the future, it is merely necessary to project this straight line as far as is required, allowing for such modifying conditions as may be anticipated. Fig. 1 shows the result of such a plot for the company mentioned above.

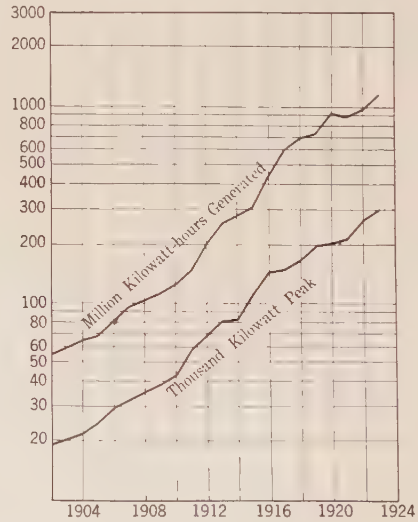

Fig. 1

If the growth does not approximate to a constant yearly percentage increase, it is only slightly more difficult to project the actual growth-curve, whatever its shape, into the future for the required period, allowing as before, for modifying conditions.

1. Research Engineer, Philadelphia, Electric Co., Philadelphia, Pa.

To be presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 9-12, 1925.

Short Term Predictions—General

The second class includes predictions of relatively short extension into the future, from one year or thereabouts down to a few hours. In this class of predictions, of course, considerably greater accuracy is desired.

To companies working under an operating budget system, it is important to predict the monthly outputs for each month of the budget year, in order that suitable allocation can be made among the individual stations and proper allowance made for fuel cost, etc. The prediction of daily peak demand for several months ahead is of value in arranging construction and major maintenance schedules. It is useful to a load dispatcher to know, on any given day, (in the middle of the afternoon, for instance) what peak demand he must expect that day, particularly so, if the day is unusually dark and stormy, making probable a high peak and preventing the direct use of the days immediately preceding as a guide.

In the following analysis the term "normal midweek day" will be used extensively. Tuesdays, Wednesdays, Thursdays and Fridays will be designated "normal midweek days;" omitting, however, any of these which happens to be a half holiday, a full holiday or the day after a full holiday. For instance, in the week containing Thanksgiving Day, there are only two "normal midweek days," Tuesday and Wednesday.

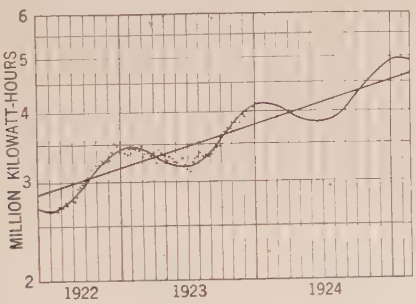

Fig. 2

Short Term Predictions—Kilowatt-hour Output

Probably everyone who has investigated the variation of central station output throughout the year has observed the periodic nature of this variation. On more or less rational grounds, based on the practically single-frequency harmonic variation of the principal cause of the output variation (the variation of the hours of daylight), the presence of a single-frequency harmonic component in the output variation would be suspected. But as output data are usually available by calendar months, the regular character of the periodicity is not apparent. Two factors account for this; first, the varying number of days per month, and second, the varying number (both among different months of the same year and among corresponding months of different years) of normal midweek days, Mondays, Saturdays, Sundays and holidays per month.

In eliminating the effect of these factors, the value of using only the normal midweek day outputs or, better still, the average of these for each week, is shown by Fig. 2. The points plotted on this chart indicate the average normal midweek day output for each week of 1923 and of the latter part of 1922. Semi-logarithmic paper has been used for this plot because it is natural to expect the growth during short periods of time to partake of the same exponential character as that over longer periods.

It is comparatively easy to insert by inspection an inclined base line having superimposed on it a sine curve which approximates the plotted points quite closely.

In inserting this base-line, it should be noted that its height and inclination are determined by the requirements that its alternate intersections with the group of plotted points must be exactly one year apart; also that the upper and lower lobes of the curve must be of equal heights. It is to give an additional point of intersection that the extension into the preceding year is made.

The form of the equation expressing this curve analytically is

$$y = J\,e^{kr}\,[\,1 + L\cos\,(0.986\,r - M\,)^\circ\,] \qquad \textbf{(1)}$$

in which e is the base of the natural system of logarithms; r, the number of days (positive or negative as the case may be) counted from a given zero date; and J, k, L and M—parameters to be determined for each curve.

The coefficient 0.986 is the ratio of 360 (the number of degrees in a circumference) to 365.25 (the average number of days in a calendar year).

In the equation (**1**), the term $J\,e^{kr}$ represents the base line. When $r = 0$

$$J\,e^{kr} = J$$

In Fig. 2, if January 1, 1923, is taken as the zero date, J is equal to 3,190,000,—the ordinate of the base line at that date.

The value of k is given by the slope of the base line. For instance, on January 1, 1923, ($r_0 = 0$) $J\,e^{kr} =$ 3,190,000; on January 1, 1924, ($r_1 = 365$) $J\,e^{kr} =$ 3,800,000.

$$\frac{J\,e^{kr_1}}{J\,e^{kr_0}} = \frac{e^{365k}}{e^0} = e^{365k}$$

$$\frac{3{,}800{,}000}{3{,}190{,}000} = 1.192 = e^{0.176}$$

$$e^{365k} = e^{0.176}$$

$$k = \frac{0.176}{365} = .000482$$

M is equal to the number of days from the zero date to the spring intersection of the complete curve with the base line, less one fourth of 365.25; or to the number of days from the zero date to the fall intersection of the complete curve with the base line, less three-fourths of

365.25. In Fig. 2, M has been found to have the value 2.

Let r_2 be the value of r which makes the expression $(0.986\,r - M)$ equal to zero; and let y_2 be the corresponding value of y. Then

$$L = \frac{y_2}{J\,e^{k r_2}} - 1$$

In Fig. 2, $r_2 = 2.025$, and the date is January 3, 1923. On that date, $y = 3{,}460{,}000$ and $J\,e^{kr} = 3{,}193{,}000$; therefore,

$$L = \frac{3{,}460{,}000}{3{,}193{,}000} - 1 = 0.0836$$

The complete equation representing the curve of Fig. 2 is then

$$y = 3{,}190{,}000\,e^{0.000482r}\,[1 + 0.0836\cos(0.986\,r - 2)°]$$

It would, of course, be possible to locate this curve and deduce the values of the parameters by strictly analytical methods, using least squares, etc.; but the labor of doing this would not be justified by the accuracy and consistency of the data.

If no change is expected in the rate of growth, the base-line and sine-curve are projected into the ensuing year with the slope unchanged. If, however, it is expected that other influences, not predictable from past performance, will affect the rate of growth, either upward or downward, the inclination of the base-line and consequently of the sine curve, must be modified accordingly. In either event, the ordinate of the projected curve at any point gives the value of the kilowatt hour output for an average normal midweek day at the date corresponding to the abscissa.

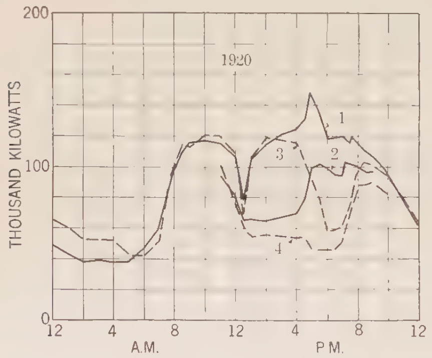

Fig. 3—Curve 1—Monday, Nov. 29
2—Saturday, Nov. 27
3—Thursday, May 27
4—Saturday, May 22

To derive the monthly outputs from the values for normal midweek day output throughout the year, it is necessary to determine the number of normal midweek days' output to which each week's output is equivalent. It has been found in the experience of the company mentioned above that the following relations hold quite closely among the days of any week:

Average of normal midweek days	1.00
Monday or day after full holiday	0 96
Saturday or half holiday	0.86
Sunday or full holiday	0.57

By combining these multipliers correctly for each week or fraction in a month, the total monthly output may be estimated.

The method here outlined may not give greatly superior results to purely empirical estimating by one thoroughly familiar with the characteristics of load variation for a number of years; but it is much more desirable in that it affords a logical analytical basis for estimating instead of placing dependence entirely upon a "trained guess."

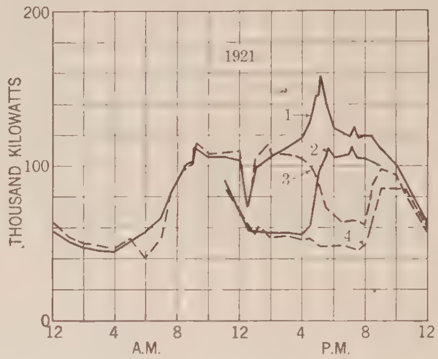

Fig. 4—Curve 1—Tuesday, Dec. 6
2—Saturday, Dec. 3
3—Friday, June 17
4—Saturday, June 18

Short Term Predictions—Peak Demand

The following analysis of daily load curves is valid only for systems whose seasonal load variation is unrestrained. For instance, it does not apply to the 25-cycle load of the company mentioned earlier, because the demand in this system is restricted by contract limitations; all demand above a definite value being carried by another system in parallel. It is applicable, however, to the 60-cycle system of this company and the accompanying illustrations are taken from load curves of this system.

The analysis is based on the separation of that portion of any daily load curve starting about 2:30 P. M. and ending about one and one half hours after sunset into three components—a constant "base load," an "afternoon block" and an "evening block." In Fig. 3 are shown typical summer and winter week day load curves for the year 1920, and portions of the load curves for adjacent Saturdays. The portions of the Saturday curves which resemble closely the week day curves, are omitted for clearness. Figs. 4 and 5 show corresponding sets of curves for the years 1921 and 1922. In the summer curves of all these charts, the outlines of the upper parts of the afternoon and evening blocks are easily distinguishable, since the superposition of the blocks is of negligible effect, except in the lower parts

on weekdays. The winter curves present greater difficulties; and it is particularly in reference to these that accurate predictions are usually of value.

Purely empirically, it has been found that the lowest value of an adjacent Saturday afternoon is suitable as a value of the constant base load for week days. Rationally this choice is not without justification, since on Saturday the afternoon block is practically negligible.

Fig. 6 shows typical winter load curves only for the year 1923, a week day and an adjacent Saturday. In this figure the separation of the week day curves into three components has been made graphically, the base load (which will be designated C) being equal to 96,000 kw.; the maximum value of the afternoon block (which will be designated A) being 76,000 kw. and the maximum value of the evening block (which will be designated B) amounting to 105,000 kw. By inspection it is found that the highest combination of the afternoon and evening blocks which can be made occurs at 5 o'clock, when the afternoon block has the value of

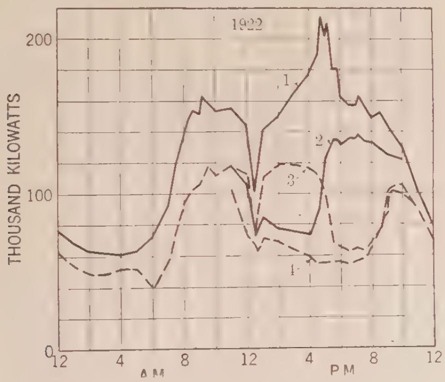

FIG. 5—CURVE 1—THURSDAY, DEC. 14
2—SATURDAY, DEC. 9
3—MONDAY, JUNE 26
4—SATURDAY, JUNE 24

56,000 kw. and the evening block the value 101,000 kw. The resultant of the three components is then 96,000 plus 56,000 plus 101,000 = 253,000 kw. The actual peak of this curve occurred at 4:57 P. M., and amounted to 250,000 kw.

For any given date, the portion of the daily load curve under consideration can be closely represented by an expression of the form

$$z = A\,F\,(t) + B\,f\,(t) + C \qquad (2)$$

in which t = hours P. M.

$F\,(t)$ is a function of t, whose analytical form is as yet undetermined, defining the shape of the afternoon load block; and similarly $f\,(t)$ with respect to the evening block. C = on a Saturday, the minimum kw. demand of the afternoon; on a week day, the minimum kw. demand of the preceding Saturday afternoon.

$$A = (\text{kw. demand at 2:30 P. M.}) - C$$

When the load curve is such that the value of the afternoon block 1.5 hours after sunset is negligible (on Saturdays through the entire year, and on week days from spring to early fall) B = (kw. demand 1.5 hours after sunset) $- C$. But the days, when the presence of an appreciable afternoon block component 1.5 hours after sunset masks the value of B, are just the days for which a knowledge of its value is most desired—namely, late fall and winter week days. For these days B must be determined in another manner, to be described later.

The demand at 2:30 P. M. has been chosen for determining A, because at that time complete recovery from

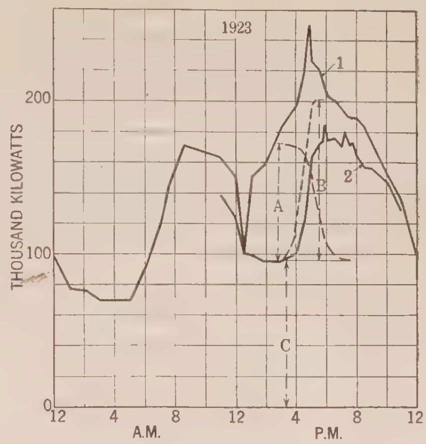

FIG. 6—CURVE 1—THURSDAY, DEC. 20
2—SATURDAY, DEC. 15

the noon dip has been made, and also the value of the evening block is negligible, even at the season of maximum overlap.

The choice of 1.5 hours after sunset as the time for determining the value of B was likewise guided by the fact that at that time the rise of the evening block to its maximum value is complete, and also, even in the

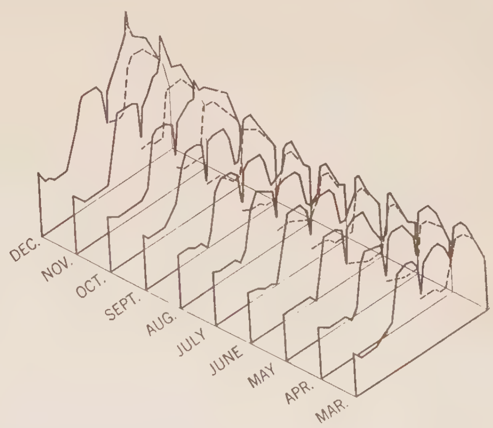

FIG. 7—TYPICAL WEEKDAY LOAD CURVES (SOLID), AND PORTIONS OF SATURDAY LOAD CURVES (DOTTED) FOR EACH MONTH FROM MARCH TO DECEMBER, 1923.

summer, no falling off from this maximum has occurred.

Fig. 7 shows the seasonal variation for the year 1923 in greater detail. It is a diagrammatic form of the Annual Load Relief Map, described in a paper by W. L. Robertson (TRANS. A. I. E. E., Vol. 36, p. 1073); using for the sake of clearness only a single pair of curves per month.

Inspection of Figs. 3, 4, 5, 6 and 7, conveys the impression that both functions, $F(t)$ for the afternoon drop-off and $f(t)$ for the evening pick-up, are exponential in character. This impression is confirmed if for each of these functions superposed curves for a large number of days, taken in various years and at various seasons, are plotted.

It is easy to derive comparable values of these functions, suitable for superposing, from the data available in the daily load curves. Division of the load curve values, $A\,F(t)$ and $B\,f(t)$, by A and B respectively, gives directly the corresponding values of $F(t)$ and $f(t)$, which may then be expressed either as decimals or in percentage for plotting.

It has been found that the composite plot of the afternoon block curves can be well represented by the curve of Fig. 8, for which equation is of the form

$$F(t) = e^{-[a(t-p)]^4}$$

in which p is the zero time at which the decrement commences; and a is the reciprocal of the number of hours from p to the time when the value of $F(t)$ is e^{-1} or 0.368, since when

$$e^{-[a(t-p)]^4} = e^{-1},\ [a(t-p)] = 1 \text{ or } a = \frac{1}{t-p}$$

The insertion of the particular values of p and a taken from Fig. 8 results in the equation

$$F(t) = e^{-[0.429(t-3.15)]^4}$$

It is found that the composite plot of the evening block curves is best fitted, not by a single curve, but by a family of similar curves, forming a band about 20 min. in width. The extreme curves of this band—those for a clear day and for a very dark day—are shown in Fig. 9.

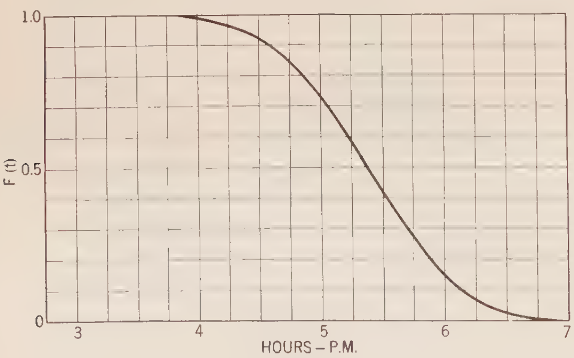

FIG. 8

For any condition of cloudiness between these extremes, a correspondingly intermediate curve would represent the evening block. The form of the equation of these curves is

$$f(t) = e^{-[b(h+q-t)]^2}$$

in which h is the time of sunset, hours P. M.; q is the number of hours from h to the zero time when the maximum value of the evening block has been reached; and b is the reciprocal of the number of hours from the time when the value of $f(t)$ is e^{-1} or 0.368 to the zero time, $h + q$.

The following particular values are met in the curve family of Fig. 9:

b is equal to 1.

q ranges from 1.25 for a clear day to 0.917 for a very dark day.

h varies nearly harmonically through the year, from about 4:20 P. M. in late November and early December to about 7:15 P. M. in late June and early July.

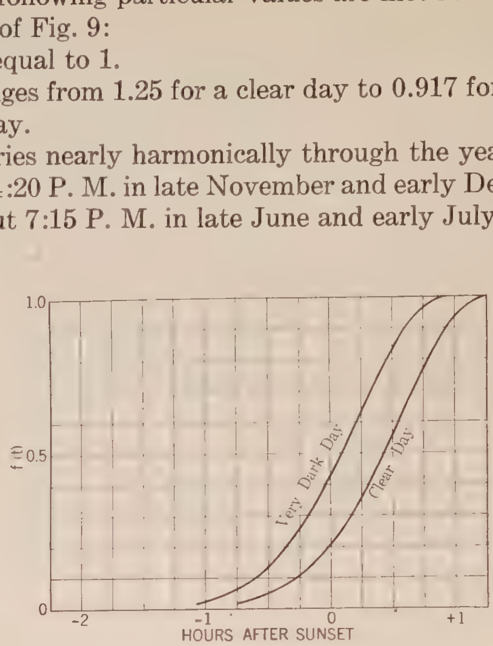

FIG. 9

The method of determining the value of B for weekdays during the period of overlap of the afternoon and evening blocks, rests on a relation observed between the Saturday and week day values of B through the remainder of the year. Reference to Fig. 7 will indicate the existence of a ratio approximately constant between the Saturday and week day values of B for the months March to September inclusive. Table I, giving numerical values of A, B and C taken from the curves of Fig. 7, confirms this indication and shows that the approximate value of the ratio is 0.75.

Assuming the ratio 0.75 to hold also for October, November and December, the week day values enclosed in parentheses have been derived from the corresponding observed Saturday values; and these derived values have been used successfully in estimating the week day peak.

TABLE I
VALUES OF A, B AND C IN THOUSAND KILOWATTS FOR THE LOAD CURVES OF FIG. 7

Weekday	Saturday	A Weekday	B Weekday	B Saturday	C Weekday and Saturday
March 5	March 3	75	85	65	70
April 6	April 7	80	85	63	67
May 11	May 12	80	80	60	65
June 13	June 9	85	75	55	65
July 11	July 7	85	65	50	65
Aug. 3	Aug. 4	80	65	50	70
Sept. 25	Sept. 22	85	80	65	75
Oct. 19	Oct. 20	82	(93)	70	80
Nov. 15	Nov. 10	80	(96)	72	85
Dec. 20	Dec. 15	76	(105)	79	96

Since the analytical form of each component of the portion of the daily load curve under consideration has now been determined, with suitable values of the para-

meters for various conditions, it would be possible, when it is desired to find the time and value of the peak for any particular date, to set up the complete equation, inserting for h its proper value taken from a table or curve, and for q a value depending on the state of the weather; to differentiate with respect to t; to equate the derivative to zero; and to substitute the value of t thus obtained in the original equation. This procedure, however, would be out of the question by reason of its complexity. A graphical method, much simpler but equally accurate, has been developed to overcome this difficulty.

Equation (2) is repeated here in the functional form rather than in the analytical form, since, in the graphical method, it is not necessary that the analytical expression for each of the functions $F(t)$ and $f(t)$ be known, nor even that they should be capable of being expressed analytically.

$$z = A\,F(t) + B\,f(t) + C \tag{2}$$

Differentiating (2) with respect to t.

$$\frac{dz}{dt} = \frac{A\,dF(t)}{dt} + \frac{B\,df(t)}{dt}$$

Equating to zero and dividing by A,

$$\frac{dF(t)}{dt} + \frac{B}{A}\,\frac{df(t)}{dt} = 0$$

$$\frac{dF(t)}{dt} = -\frac{B}{A}\,\frac{df(t)}{dt} \tag{3}$$

Geometrically, the term $\frac{dF(t)}{dt}$ represents the slope of the curve of Fig. 8 at any value of t; while the term $-\frac{df(t)}{dt}$ represents the slope, not of one of the curves of Fig. 9, but of its negative—that is, a curve having ordinates of the same absolute value, but extending downward from the horizontal axis. The term $-\frac{B}{A}\,\frac{df(t)}{dt}$ correspondingly represents the slope of a curve whose ordinates are $-\frac{B}{A}$ times those of one of the curves of Fig. 9; and whose functional form is therefore $-\frac{B}{A}\,f(t)$.

Equation (3) indicates that the geometrical condition for a maximum of z is that the slopes $\frac{dF(t)}{dt}$ and $-\frac{B}{A}\,\frac{df(t)}{dt}$ shall be equal. Fig. 10 shows the graphic method of accomplishing the solution. In this figure, the solid lines indicate lines drawn on a fixed sheet, the solid curve being a repetition of the curve of Fig. 8 and the fine vertical line being drawn at the time of earliest sunset; while the dotted lines indicate lines drawn on a sheet of tracing cloth, celluloid or other non-opaque material, which is adjustable to any desired position on the fixed sheet. The curves on the movable sheet are members of the family represented by $-\frac{B}{A}\,f(t)$, taken for values of $\frac{B}{A}$ ranging, as indicated, from 0.6 to 1.4 at intervals of 0.2. On the sheet the variation in position of the curves, with respect to the time of sunset, due to weather conditions, is taken into account, not, as in Fig. 9, by having a single axis of sunset time and shifting the curves between the extremes shown, but by having a single set of curves and shifting the axis of sunset time correspondingly.

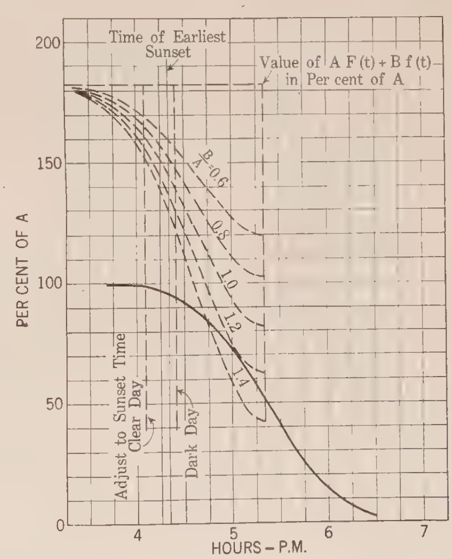

FIG. 10

In using these sheets, it is, of course, necessary to maintain the horizontal and vertical axes of the movable sheet horizontal and vertical with respect to the fixed sheet.

In order that times on the movable sheet and on the fixed sheet shall correspond, either one of the extreme positions of the sunset axis on the movable sheet or some intermediate position (depending on the state of the weather) must be adjusted to coincide with the time of sunset as read on the scale of the fixed sheet. Then, holding this horizontal setting, the movable sheet must be adjusted vertically until the curve bearing the correct value of $\frac{B}{A}$ is tangent to the curve on the fixed sheet. At the point of tangency the slopes of the two curves are equal, and this satisfies the condition of Equation (3) for a maximum value of z.

Not only does the abscissa of the point of tangency

indicate the time at which the peak occurs; but also the ordinate of the point of tangency gives the value of the afternoon block in per cent of A at that time, and the height from the point of tangency to the horizontal axis of the movable sheet, read on the scale of the fixed sheet, indicates the value of the evening block at the same time, likewise in per cent of A. Therefore, the ordinate of the horizontal axis of the movable sheet, read on the scale of the fixed sheet, gives the value of the sum of the afternoon and evening blocks.

In the particular example shown in Fig. 10, $\frac{B}{A}$ is 1.2 (this would be the case if B were 90,000 and A 75,000 kw., for instance), the day is very dark and sunset occurs at 4:25 P. M. When the movable sheet is adjusted horizontally so that the line for a dark day coincides with the time 4:25 P. M. on the fixed sheet, and vertically so that the curve $\frac{B}{A} = 1.2$ is tangent to the curve on the fixed sheet, the abscissa of the point of tangency gives 5:03 P. M. as the time of the peak, and the ordinate of the horizontal axis of the movable sheet gives the value of $[A\,f\,(t) + B\,f\,(t)]$ as 182.5 per cent of A. The peak value of the load curve is then given by the equation

$$z = C + 1.825\,A$$

The estimation of peak demands by any method based on the values of the actual total peak for corresponding periods of past years is open to several criticisms. In such a method, no consideration is taken of the possibility that one or more of the previous years may fail to give a reliable indication, on account of the absence of stormy weather at the time of the peak. It is also tacitly assumed that the shape of the load curve remains constant. This assumption is equivalent to the assumption that the three components, A, B and C, distinguished in the present investigation, increase in the same ratio; and this assumption is not justified.

Furthermore, it is difficult not only to make a reliable estimate of the peak at a given date in the future, but also to correlate and check such an estimate, when made, with actual peaks as the given date approaches.

On the other hand, the separation of the components of past peaks allows the growth of each component to be observed individually, regardless of whether or not it has been combined at any particular date with the maximum overlap. It is then relatively simple to project the growth of each component, at its own growth-rate, to the desired date, and to combine the estimated values properly.

The reliability of an estimate of peak prepared in this way results both from the accuracy with which the individual components may be predicted and from the probability of compensating errors in the values of the components.

A great advantage in this method is that, after an estimate has been made, it may readily be checked at any time as the date approaches by noting whether the values of the components taken from current load curves confirm the original estimate or indicate the necessity of a revision.

CONFERENCE ON ELECTROPLATING

A conference of electroplaters was held at the Bureau of Standards on November 14 and 15. The papers presented covered the progress which has been made in the Bureau's laboratories in connection with electroplating research as well as the experience of those engaged in the commercial application of the subject. Valuable suggestions were made as to the lines along which future research can most profitably be directed.

Mr. C. T. Thomas of the Bureau's staff presented a paper covering the protective value of nickel deposits. This was illustrated by exhibits of specimens which had been plated with nickel and then subjected to various corrosive agencies. In the present state of the art, it was brought out, the protection afforded by nickel plating is far from complete, and it does not seem likely that any single discovery will solve the problem once for all. It will be a matter of slow improvement in plating methods as the result of increasing scientific knowledge of the process of electroplating and of the numerous variable that affect it.

Mr. M. R. Thomas, also of the Bureau's staff, described the studies now in progress in connection with the nickel plating of zinc and die castings. This is an important matter because of the increasing use of die castings for automobile trimmings and other nickel plated objects which were formerly made of brass. The metals used for making such parts are largely alloys containing zinc, and are cast in steel molds which can be used over and over.

Other researches in progress at the Bureau were discussed, including studies of nickel anodes, the effect of impurities in nickel salts, measurements of the hydrogen ion concentration, and the throwing power of nickel-plating solutions. The ideal solution would be one that would give an even deposit all over, and this is still far from being attained. It is now possible, however, to make a solution which will give much better distribution of nickel than could be obtained a few years ago.

Appropriate subjects for future research were discussed; these including methods of plating various metals, methods of analysis, and instruments for measuring the properties of solutions and of deposits. The best means to secure effective cooperation between the Bureau of Standards, the American Electroplaters' Society, the American Electrochemical Society, and other technical organizations was also considered, as well as proposed specifications for nickel and silver plating, and the technical education of electroplaters by means of classes at the factories and through college courses in electrodeposition.

About 45 delegates attended the conference, which was followed by an inspection trip through the Bureau's laboratories.

Use of an Oscillograph in Mechanical Measurements[1]

BY HARVEY L. CURTIS*
Associate, A. I. E. E.

I. Introduction

THE oscillograph is an instrument which has been extensively employed by electrical engineers in electrical measurements. It has been used not only in connection with electrical oscillations, such as alternating electromotive forces and alternating currents, but also in connection with acyclic electrical phenomena, such as the current required to blow a fuse, or the discharge current of a condenser. This paper describes methods by which the oscillograph may be used in mechanical measurements. This requires that the mechanical phenomena must affect an electric current which is being continuously recorded on the oscillograph.

II. The Oscillograph

The oscillograph can be briefly described as a galvanometer having a short period and critical damping, which is so arranged that its deflections can be recorded on a moving photographic film. Several models have been brought out by different manufacturers. For the work described in this paper a General Electric oscillograph has been modified to meet the requirements of the special investigations. The most important of these modifications are: (1) A special arc lamp; (2) a large drum which will take a five-foot film; (3) a special table on which is mounted a switchboard and suitable control instruments; (4) a new shutter and shutter control mechanism; (5) a rotating mirror; (6) a tuning fork for measuring the speed of the film.

1. *Special Arc Lamp.* Experiments have been made with several different sources of light, but for the highest film speeds it is necessary to use an arc lamp. For this purpose it is essential that the end of the positive carbon shall lie in the axis of the lens which is used to direct the light beam onto the oscillograph mirrors and very near to the focal point of the lens. It must be possible to advance this carbon without disturbing its adjustment. To accomplish this a special arc lamp was constructed in which the carbon holders slide on metallic ways. The carbons are held in V-shaped grooves which are parallel to the direction of the ways. The carbon holders are advanced by means of racks and pinions. The carbons can be maintained in a desired position by keeping their images, formed by a pinhole camera, at definite points on a screen which is provided for this purpose.

2. *Large Drum which Will Take a Five-Foot Film.* It is often desirable to use films of considerable length and whose motion is uniform during the time that the record is being made. For this purpose drums have been constructed which will take a five-foot film. This length was selected as it corresponds with standard films which can be universally purchased. The rotating portion has a large moment of inertia which insures that the speed will not change rapidly. The opening of the shutter does not appreciably change the speed of the drum.

3. *Special Table on Which is Mounted a Switchboard and Suitable Control Instruments.* Another useful modification was the design of a special table on which there is mounted not only the oscillograph itself but also a switchboard and suitable measuring instruments. This table was especially constructed for field use. The legs are made of two-inch pipe which screw into floor flanges that are mounted on the underside of the table top. The switchboard is hinged to the table apron in such a way that when the legs are removed it will swing into the bottom of the table, where it can be fastened for shipment. The instruments are mounted at a convenient point at the back of the table. These instruments consist of a 25-ampere ammeter for reading the current through the arc, a one-ampere ammeter for reading the current in the field magnet, and three milliammeters, range 150-0-150, which are connected in series with the oscillograph elements. These latter instruments have proven to be especially useful, since most of the difficulties in oscillograph operation occur in the element circuits. These difficulties can readily be traced by means of these milliammeters. In addition, there is a small resistance box in each element circuit, variable from 1 to 1000 ohms in steps of one ohm.

In Fig. 1 is shown an illustration of a complete oscillograph with arc lamp, large drum, instruments, and switchboard. At the right in this picture is the table with switchboard as prepared for shown shipment.

(4). *New Shutter and Shutter Control Mechanism.* There are many advantages to be gained by placing the shutter mechanism as near the film as possible. By doing this all of the optical parts can be continuously illuminated so that one can readily see whether they are in proper adjustment. Moreover, by placing the shutter at this position, the time required to open it is reduced to a minimum. Another advantage of placing the shutter in this position will be discussed in connection with the rotating mirror which will be

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1. Approved by the Director of the U. S. Bureau of Standards.

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described in the next section. A diagram showing the location of the shutter and its method of operation is shown in Fig. 2.

It is important to have a mechanism which will

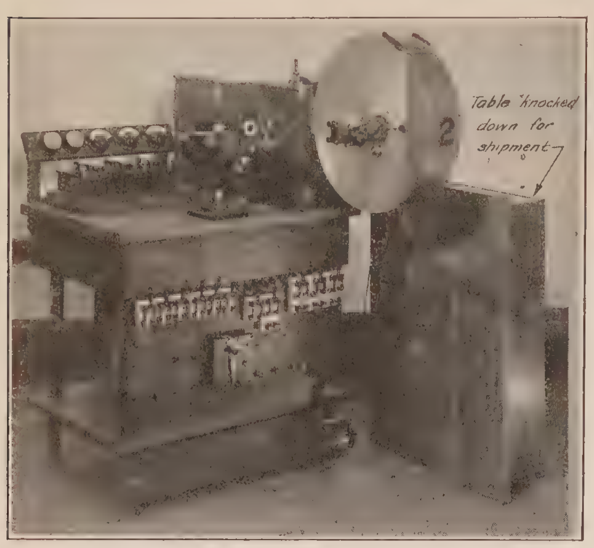


FIG. 1

The oscillograph with large drum, arc lamp, ammeters, resistances, and switchboard mounted on a special table. To prepare the table for shipment, the legs are removed and the switchboard, which is hinged to the apron of the table, is folded against the bottom of the table top without disturbing the wiring.

close the shutter when the film drum has made a complete revolution, and it is desirable that it shall do this regardless of the speed of the drum. It should also be as nearly automatic as possible so that it will

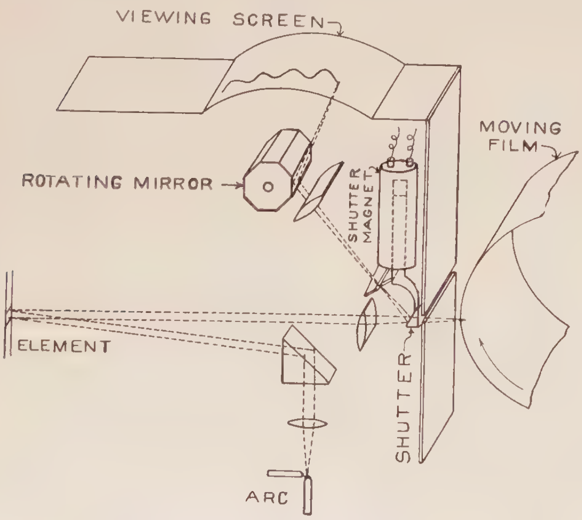


FIG. 2

Diagram to show the optical system when the shutter is placed near the film. A mirror is mounted on the shutter so that the light from an element can be seen on the viewing screen whenever the shutter is closed.

require little or no attention from the operator. This has been accomplished by the mechanism shown in Fig. 3. A brass gear is mounted either directly on the shaft of the drum or connected therewith through a train of gears so that no slipping can occur. A fiber gear is mounted on an arm in such a way that it is normally held out of mesh from this brass gear by means of a spring, but can be pulled into mesh by means of an electromagnet. This fiber gear has a small portion cut away. When it is rotated to the point where this portion is cut away, it presses against the brass gear and stops rotating, remaining in this position until the operator releases the key. Then as the fiber gear is drawn back by the spring to its normal position, a ratchet attached thereto (not shown in the drawing) turns it through a small angle so that no attention is required to make it ready for the next operation.

Attached to the fiber gear there is an adjustable cam

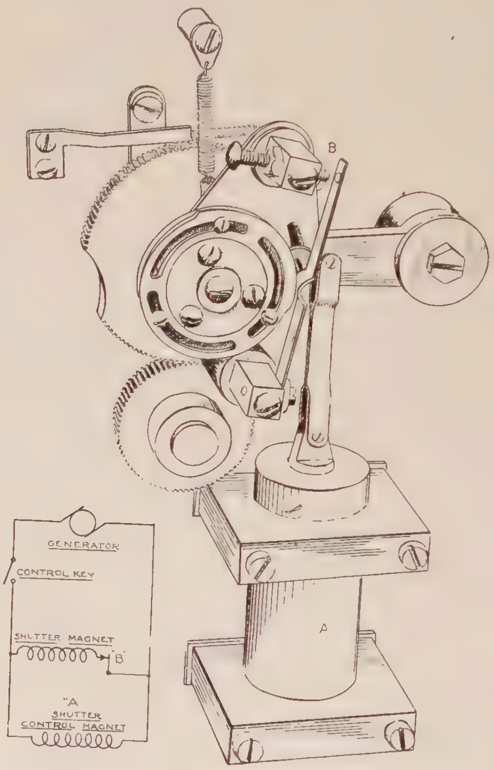


FIG. 3

The shutter-control mechanism for closing the shutter when the drum has made a complete revolution. The figure shows the gears held in mesh by the electromagnet A. The fiber gear (upper in the figure) has made about three-quarters of a revolution. The contact B is open, having been closed during the first part of the revolution.

which opens a contact in the circuit of the shutter magnet. This contact is closed when the fiber gear is in its normal position, but is opened after the gear has rotated a definite amount. By proper adjustment of the cam, the shutter can, for any given speed of the drum, be made to close when the drum has made one revolution.

The adjustment of the shutter mechanism will, in general, depend on the speed of the drum, and is more difficult for high speeds than low speeds. When the drum is rotating rapidly, the time required for the shutter to open, the time required for it to close, and the time required for the fiber gear to be drawn into mesh, are each a large fraction of the time of a revo-

lution of the drum. That the adjustment of the shutter mechanism will depend on each of these can be seen by considering a simple case. Suppose that the gear is drawn into mesh at the same instant that the shutter is opened. Then the shutter circuit will be broken when the drum has made a definite part of a revolution, at which time the shutter starts to close. In the time required for the shutter to close, the drum will rotate through an angle which depends upon its speed of rotation. Hence with this arrangement, if the shutter mechanism was adjusted to work correctly at low speeds, there would be overlapping at high speeds.

The adjustment of the shutter mechanism will be independent of the speed of the drum if the time of closing the shutter is shorter than the time of opening the shutter by the time required for the shutter-closing mechanism to operate. Another way of stating this is that the shutter must open so slowly that it will be closed for a time after the fiber gear comes into mesh, and this time must equal the time required to close the shutter. Up to the present time, it has been found necessary, in order to accomplish the above results, to make the time of opening the shutter about five-hundredths of a second. As this is not satisfactory for some kinds of work, it is frequently more desirable to adjust the shutter to open as rapidly as possible, and then adjust the shutter closing time for a definite speed of the drum. When the speed of the drum is materially changed, it is then necessary to readjust the time of closing the shutter.

(5). *Rotating Mirror.* As indicated in Fig. 2, a mirror set at an angle is mounted directly on the shutter so that whenever the shutter is closed the light is reflected through a slit and a second cylindrical lens onto one of the faces of a hexagonal rotating mirror. This mirror reflects the light onto a translucent viewing screen. When used with acyclic phenomena, this hexagonal mirror is not rotated but can be turned to bring the spots of light at a convenient place on the viewing screen. Its principal value is that it enables the operator to see that the spots of light reflected from the element mirrors are in adjustment and are sufficiently brilliant. With cyclic phenomena the rotating mirror can be driven by any variable speed motor, the speed being adjusted so that suitable waves appear on the viewing screen. It should be observed that these waves are slightly distorted and that they do not have quite the same amplitude as the waves which will be photographed on the moving film. In any case, the spots of light which are about to be photographed can be observed up to the instant that the shutter is opened, and they come into view again as soon as the shutter is closed.

6. *Tuning Fork for Measuring the Speed of the Film.* In many experiments it is important to measure the speed of the film with greater accuracy than can be done by the use of a 60-cycle wave. This has been accomplished by means of a tuning fork which is installed in the oscillograph. The principle involved in the use of the tuning fork is shown in Fig. 4. On each prong of the tuning fork there is mounted a vane, these vanes being of such length that they overlap when the tuning fork is at rest. Slits are then cut through these vanes so that, when the tuning fork is at rest, the slits in the two vanes coincide. When the tuning fork

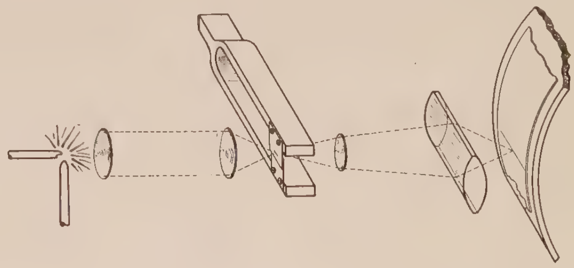


Fig. 4

Diagram showing optical system by which a tuning fork can produce timing lines on a moving film.

vibrates, the slits coincide at the center of the swing, giving momentarily the effect of a single slit. When this slit is brilliantly illuminated, its image, formed by a suitable optical system, can be photographed on a moving film. This gives lines on the film,[2] the distance

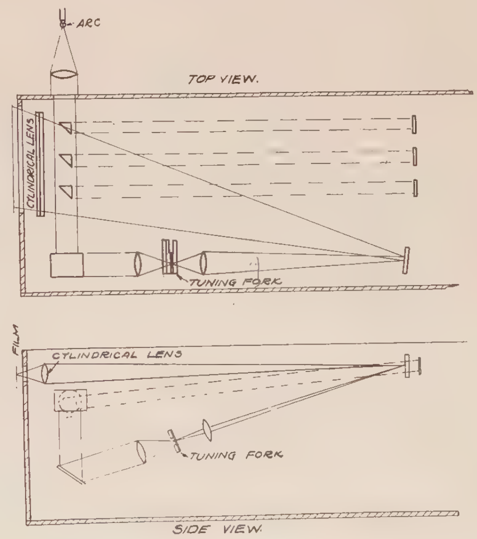


Fig. 5

Diagram showing method of installing a tuning fork in an oscillograph. By means of the tuning fork, the velocity of the oscillograph film can be accurately determined.

between them being the distance that the film travels in the time of a half vibration of the fork. A suitable size for the slits is 0.003 in. width and 0.2 in. length.

For rapidly moving films a 500-cycle fork giving lines one one-thousandth of a second apart has been found

2. A more complete description of this method of timing a moving photograph film is given in Scientific Paper 470 of the Bureau of Standards by H. L. Curtis and R. C. Duncan, entitled "A Method for the Accurate Measurement of Short-Time Intervals."

satisfactory. For slower film speeds a 50-cycle fork giving lines one one-hundredth of a second apart has been useful. A diagram showing the optical system used is given in Fig. 5. Examples of timing lines will be found in Fig. 8.

III. Measurement of Short Time Intervals

When it is desired to study the time of occurrence of a number of events, where order of occurrence is known, it is generally possible to arrange electrical circuits in such a way as to record all of these events with one oscillograph element. An example of this is the recording of the events which take place in a gun at the time it is fired. The electric circuits by which it is possible to record six different events with a single element are shown in Fig. 6.

As shown in this figure, two batteries, one of 6 and one of 12 volts, are connected in opposition so that a continuous current is sent through the resistance, R, and the oscillograph element, E. The series of events is started by the closing of the firing key, S. This ener-

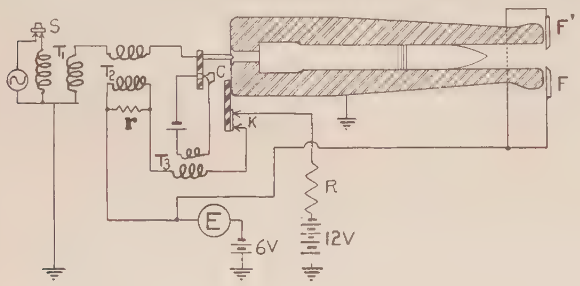


Fig. 6

Diagram showing the electrical connections for recording the important events in the firing of a gun. By circuits not shown, the oscillograph shutter is opened a few hundredths of a second before the firing circuit is closed at S. A description of the sequence of events after the closing of the firing key, and of the consequent variations in current through the element E of the oscillograph, is given in the text.

gizes the firing circuit, sending an alternating current through a fine wire inside of the primer. This wire soon fuses, thus opening the firing circuit. By means of a small current transformer, T_2, called the primer transformer, an alternating current is superposed on the direct current which is already flowing through the oscillograph element. The amount of the alternating current which flows through the oscillograph element is is regulated by a resistance, r , in parallel with the secondary of the transformer. This resistance also serves as a non-inductive path when other current changes are produced in the circuit. By means of this alternating current the time of the closing of the firing circuit and the time at which it opens are recorded on the oscillograph film. Soon after the explosive in the primer is ignited, enough pressure is generated inside the primer to cause it to explode, sending a flame into the powder chamber, and at the same time causing a sudden kick of the firing pin. As this firing pin reacts suddenly, it opens the contacts on the explosion indicator, C, causing the current through the primary of the explosion indicator transformer, T_3, to become zero. This produces in the secondary circuit of T_3 a momentary current which is registered on the oscillograph film, thus giving the time at which the explosion occurred. When the gun starts to recoil, it opens the start-of-recoil contacts, K, thus breaking the continuous current which up to this time has been flowing through the oscillograph element. When the projectile reaches the muzzle, it makes contact with the ogive finger, F', causing a relatively large current to flow through the oscillograph element. This ogive finger is swept away

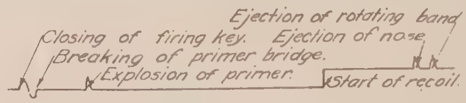


Fig. 7

Diagram showing type of record given by the circuits of Fig. 6.

when the circuit has been closed for only a few ten-thousandths of a second, thus again opening the circuit. This same process is repeated when the rotating band makes contact on the rotating band finger, F.

As these events must occur in a definite order, there is no possibility of one record interfering with any other. Moreover, since all the deflections are of a different type, if one apparatus should fail to record, no uncertainty is introduced regarding the other events. The only exception is in the case of the ogive finger and rotating band finger, whose records are practically

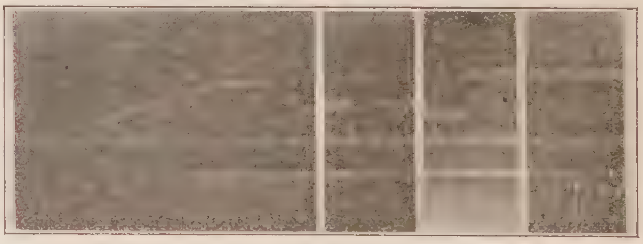


Fig. 8

Four portions of a record taken during the firing of a gun, with the circuits arranged as in Fig. 6. In the first portion is shown the alternating-current wave; in the second portion, the current change caused by the explosion indicator; in the third portion, the displacement of the record caused by the breaking of the start-of-recoil contacts; in the fourth portion, the current changes caused by the grounding of the ogive and rotating band fingers. The distance between timing lines corresponds to one one-thousandth of a second.

identical. As pointed out later, this is necessary for other reasons. It would be very simple to introduce some resistance in one of the circuits so that they could be distinguished.

The record obtained by such an arrangement is so long that it is not feasible to reproduce it. However, the kind of record which this apparatus gives is shown in Fig. 7. Portions of an actual record are shown in Fig. 8. These portions were selected to show the deflections at the times of the different events. In this record the events are shown as recorded by the element

whose trace appears at the top of the figure. The other two elements were used for other purposes. The timing lines are one one-thousandth of a second apart.

When it is desired to obtain the time of occurrence of several events, the order of the occurrence of which cannot be predetermined, it is sometimes feasible to arrange a series of circuits like that described above, so that each event gives a distinctive record on the film. Then the order of occurrence and time of occurrence can be determined from a single record. However, there is always the possibility of two events occurring approximately simultaneously so that the time at which these events occur cannot be accurately determined. When it is important to avoid such a possiblity of confusion, it is necessary to record each one of the events on a separate element. If it is necessary to use more than one oscillograph, then some common event must be recorded on all films, so that the time of each event can be determined.

It is sometimes possible, when it is reasonably sure that the events will not all occur simultaneously, to so arrange the electric circuits that at least two independent values of the time interval can be obtained on two different elements, and yet have only a very slight probability that any event will fail to be recorded. As an example, suppose that it is desired to determine with accuracy the time between the contact on the ogive finger and that on the rotating band finger in each of three guns which are fired simultaneously. As explained later, this time difference can be used to get the velocity of the projectile. But since the experimental errors are relatively large, it is important to get as many independent determinations as possible. By using three elements for three guns and connecting them so that the records from gun No. 1 are recorded by both elements 1 and 2, from gun No. 2 are recorded by elements 2 and 3, and gun No. 3 by elements 3 and 1, we are able to obtain two values for the velocity of each projectile, and there can be no uncertainty regarding the value for each gun. Should the times at which two projectiles reach the muzzles differ by less than one one-thousandth of a second, then the record of one element would be of no value, but the records of the other two would be sufficient to give one value for two guns and two values for one gun. Should all three guns react simultaneously, then the records would be valueless, but the probability of such a contingency is very remote.

IV. Measurement of Velocity

If at definite points in its path a moving object changes the electric current in a circuit, then by recording the changes in current on an oscillograph film whose speed is known, it is possible to determine the velocity of the moving object. Since the oscillograph can measure short time intervals, this method has been used chiefly in measurements on objects moving at very high velocities. Perhaps the highest velocities with which engineers at present have to deal are those of projectiles fired from modern guns. Their velocity is of the order of 3000 ft. per second or 3 ft. in one one-thousandth of a second. With an oscillograph film running at 50 ft. per second, the film moves approximately one-half inch in one one-thousandth of a second. With a suitable record, this distance can be measured by means of a comparator with an accuracy of one-fifth of one per cent. However, to obtain this accuracy in the time measurement it is necessary to record both events on one element and to arrange the circuits for recording the two events so that the electrical constants are practically identical in the two cases.

The necessity for using a single element arises from two causes; first, the spots from two elements cannot be adjusted so that they lie exactly on a line parallel to the axis of the drum, and second, the rotational constants of the two elements cannot be made identical. Neither of these causes will introduce errors of more than one or two hundred-thousandths of a second, but in the short interval under consideration, this might produce an error of one or two per cent in the final result.

The necessity for the identity of the electrical constants of the circuits for recording the two events arises from the necessity of a time correlation of the element deflection with the change of current in the circuit. When the projectile closes an electric circuit, the current starts at zero and rises to its maximum by means of an exponential curve, the shape of which depends on the resistance and inductance of the circuit as well as on the applied electromotive force. The element deflects slowly at first, but with a rapidly increasing velocity, partly because the current is increasing and partly because of its own inertia. Hence it is difficult to determine on the film the exact time that a deflection starts. The time difference between two events can, however, be determined with accuracy by taking as the time of the first event the time that the element has deflected one centimeter, say, and an equal deflection for the time of the second event. However, this will accurately determine the time interval only when the electric circuits for the two events have the same constants, and when the rotational constants of the two recording elements are the same. This last is completely met by recording both events on one element. The desirability of measuring from a deflected position is apparent from the center trace of Fig. 8, but it is not to be expected that this will be so apparent in a reproduction as in the original film.

The measurement of the distance between contacts generally introduces a greater error in the velocity when measured by an oscillograph than does the measurement of time. Two methods of obtaining a measurable distance have been used. In the first, each contact consists of two insulated metal plates or screens, so that the projectiles short-circuits them. It is

desirable to put a quick acting fuse in the circuits with the first contact so that if a short circuit persists the fuse will melt and the element will have returned to its zero position before the second contact is closed. In the practical application of this method, it is not generally feasible to measure the distance between the contacts with an accuracy as great as one-tenth per cent. As they are generally thirty or more feet apart, so that the time interval is of the order of a hundredth of a second, little difficulty is experienced in measuring the time to a greater accuracy than is possible in measuring the distance.

In the second method, two contacts are mounted in

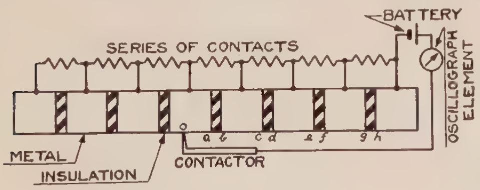


FIG. 9
Diagram to illustrate the step-by-step method.

the same plane to make contact at definite points on the projectile. This is illustrated in Fig. 6 where the ogive finger and rotating band finger are in the same plane, the one making contact on the ogive of the projectile and the other on the rotating band. This method, which is applicable only to projectiles of large size, requires that the distance on the projectile shall be measured before the projectile is loaded and that the path of the projectile shall be known so that the contacts will be made at the measured positions. This last difficulty may introduce errors as great as one per cent. Hence this method should be used only when no other method is available.

V. MEASUREMENT OF DISPLACEMENT BY THE STEP-BY-STEP METHOD

It is sometimes desirable to determine the time-displacement curve of a moving body. This is readily accomplished by means of the oscillograph by so arranging an electric circuit that the current is changed as the body passes certain definite points. This step-by-step method is shown diagrammatically in Fig. 9, which shows the principles involved in a displaceometer. This instrument is designed to obtain time-displacement curves of the motion of a body in one direction. The series of contacts is mounted on a fixed support while the contactor is attached to the body whose displacement is to be measured. When the body moves, the contact point is drawn over the contacts, thus altering the resistance of the circuit and producing a definite record on the oscillograph film. When the contact point is on an insulating segment, the current goes to zero but rises to a definite value as it comes onto one of the contacts. A record obtained with such an instrument is shown in Fig. 10.

One advantage of this method is the great accuracy which can be obtained by its use. Both time and distances can be measured with high precision. Also, the method is very flexible. For example, in determining the recoil of a gun, the motion is slow at first but changes rapidly. At the beginning, contacts may be made to advantage every one-tenth inch. However, with increasing velocity, these could not be recorded satisfactorily, so that after the first inch it is desirable to have the contacts made every one-half inch, and later when the velocity becomes more uniform, contacts which are made every two and one-half inches have been found satisfactory. This permits greater accuracy in those parts of the curve where accuracy is needed.

The method has, however, certain disadvantages. It is obvious that one can never tell the exact instant that the motion starts. However, if the apparatus is well made so that the first contact occurs one one-thousandth of an inch or less after the motion begins, this is not a serious difficulty. In fact, by such an arrangement it may be possible to determine the time at which the motion begins with greater accuracy than can be done by some method which records the motion directly. Another disadvantage of the instrument is the fact that, if the time-displacement curve has a maximum value, this maximum value is not recorded by this method but must be determined from the plotted curve. The error in the maximum value can be diminished by arranging the apparatus so that contacts occur at frequent intervals near this point. However, when the maximum value of the occurrence is a matter of importance, care must be exercised in designing the apparatus in order that it will give the necessary accuracy.

FIG. 10
Portion of a record obtained by a recoilmeter using the step-by-step method. The distance between timing lines corresponds to one one-thousandth of a second. Contacts were one-tenth of an inch apart.

The fact that the time-displacement curve can be be obtained only by plotting the data which is read from the oscillograph film is, in some cases, a disadvantage. This becomes, however, an advantage when great accuracy is desired, since the films can be read with such accuracy that a very large sized plot can be made. This is very necessary if the time-displacement curve is to be graphically differentiated to obtain a time-velocity curve. Moreoever, the time-acceleration curve, which can be obtained by a graphical differentiation of the time-velocity curves is of value only if the time-displacement curve is constructed with

the highest accuracy. In Fig. 11 is shown the time-displacement curve of a gun during the first seven inches of recoil, together with the velocity-time curve and the acceleration-time curve. The last two curves were obtained from the first by graphical differentiation.

In analyzing the motion of a moving body, it is sometimes desirable to obtain time-displacement curves of two different parts of the mechanism from which the displacement of one part relative to the other can be determined. An interesting application of this was in determining the instantaneous torsion of the shaft of a large Diesel engine. At certain speeds the shaft of the engine showed large torsional vibrations. By placing accurately made commutators on the two ends of the shaft and recording on the oscillograph the times when the segments passed a definite position, it was possible to plot curves which showed the torsion of the shaft at any instant. Two such curves are shown in Fig. 12. It will be noted that one end of the shaft showed almost uniform rotation, whereas there is a very pronounced sine wave at the opposite end.

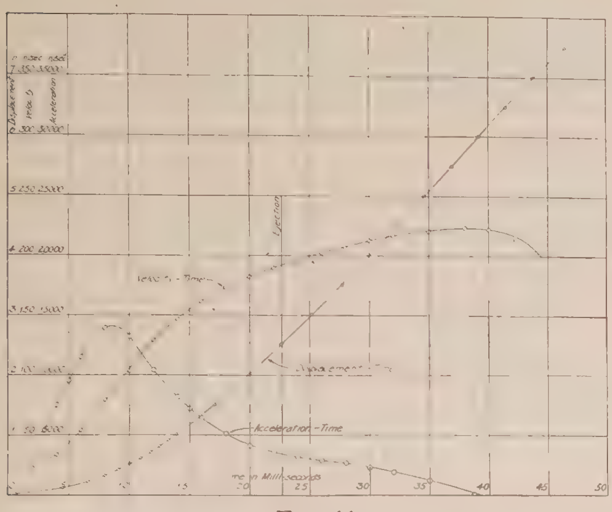


Fig. 11

Curves obtained by means of a recoilmeter during the firing of a large gun. The displacement-time curve is plotted from data obtained from an oscillograph record, together with the calibration data of the recoilmeter. By differentiating this curve graphically, the velocity-time curve is obtained. The acceleration-time curve is obtained by graphical differentiation of the velocity-time curve.

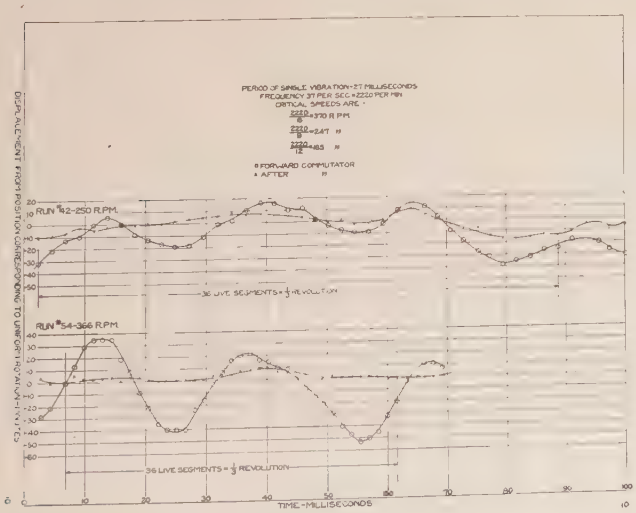


Fig. 12

Torsional vibrations of an engine shaft at two critical speeds.

The same principle can be applied in the simultaneous measurement of several displacements. If these are recorded by one or more oscillographs so that the relative times can be determined, a very complete knowledge of the motion of the body can be obtained. This has been applied to the study of the motions of the turret and turret structures on a battleship when the guns of this turret are fired. In this case eight oscillographs were used, giving twenty-four separate records. These showed not only the displacement of the turret in three perpendicular directions but also the rotation about three perpendicular axes. They likewise gave the distortions of the structures which support the turret. This complete analysis was possible not only because of the accurate timing which could be obtained through the use of the oscillograph, but also because all times could be referred to the same zero.

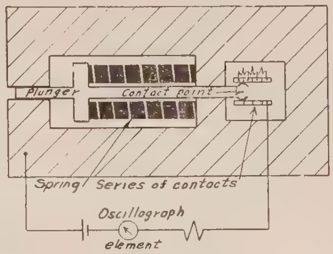


Fig. 13

Diagram of a pressure gage by means of which a pressure-time curve can be obtained when the pressure on the plunger is changing rapidly.

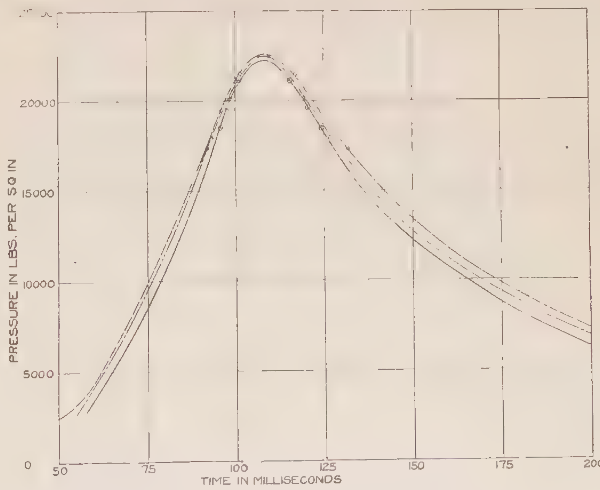


Fig. 14

Curves of pressure obtained simultaneously by three independent gages, mounted in a bomb which had a small vent. The pressure was produced by igniting a charge of powder.

VI. Application of Step-by-Step Method to a Phenomenon Which Can be Registered as a Displacement

There are many phenomena whose magnitude can be determined by means of a displacement, and hence they can be recorded on an oscillograph by the method described above. We shall indicate only one application, namely, the measurement of a rapidly varying pressure. A diagram showing the principles involved in such an instrument is given in Fig. 13. The pressure which is applied to the plunger compresses the spring. This causes the contact point to move over a series of contacts, producing a record which is identical in form with that of the displaceometer described above. In Fig. 14 are shown curves obtained by three separate pressure gages which were placed in a bomb. The pressure rose to over 20,000 lb. per square inch in approximately one-tenth of a second. A satisfactory time-pressure curve was obtained.

The illustrations in this article have been drawn from the experience of the author and details are given only insofar as it is thought necessary to make clear the principles involved. There are many other ways in which the oscillograph can be used in measuring mechanical phenomena of short duration. It should be considered whenever it is necessary to investigate a phenomenon whose duration lies between one second and one millisecond.

Several physicists and engineers have been associated with the author in redesigning the oscillograph and in developing the experimental methods herein presented. Particular mention should be made of Dr. R. C. Duncan and Mr. H. H. Moore.

A SURVEY OF CURRENT PROGRESS IN RADIO ENGINEERING*

A survey of progress in radio reveals that this is the era of radio engineering. This statement does not refer to the importance or extent of radio engineering but to the type of development now going on in radio as compared with that of past years. Relatively speaking, radio has been crude heretofore, whereas the progress now being made is not merely empirical but is more largely characterized by actual engineering development. We now have not so much the invention of devices as the perfection of them. This statement is very general. There have, of course, been triumphs of engineering in the past history of radio, and on the other hand the process of "cut and try" will continue to be used in the future. Nevertheless, broadly speaking, radio engineering has now taken definite form and is the tool by which further progress in radio will be wrought.

In the development of new and improved radio communication methods or systems, we have marked extension of the available frequency range, great improvements in directive radio transmission, advances in the perfection of selective radio systems, and engineering development of carrier-current communication. Among radio devices and applications of radio there is outstanding progress on radio beacons, on the uses of radio for air-craft navigation, on direction finders, and on radio vision. In the field of research and study of the problems of radio, we have important progress now going on in radio measurements, in standardization of apparatus, in the study and mitigation of the vagaries of wave propagation and atmospheric disturbances, and in the wide reaches of the interference problem.

The most conspicuous recent development in radio engineering is the conquest of the new domain of ultra-radio or very high frequencies (short waves). Even the existence of the vast range of frequencies above 2000 kilocycles (below 150 meters) was hardly suspected, and certainly was generally forgotten up until less than a year ago. One curious reason for the subordination of this range of frequencies has been the erroneous use of wave length in meters as an expression of radio frequencies. Radio engineering actually deals with currents which have a certain frequency. The wave length of the wave as it travels along in space can be calculated from the frequency, but it is a derived and an artificial concept.

Frequencies up to 20,000 kilocycles have come into extensive use. Actual radio services are being conducted in this region by broadcasters, transoceanic communication companies, military services, amateurs; in short, every important radio interest has begun operations between 2000 and 20,000 kilocycles. Even higher frequencies have been used in experiments.

Great improvements are in progress in directive or "beam" transmission. It is accomplished by using a number of transmitting antennas and so adjusting the phases of the current in each, in relation to their distances apart, that reenforcement of radiation is obtained in one direction and more or less neutralization of radiation in other directions. An obvious advantage of beam transmission is that much lower power is required than in ordinary radio transmission, since the transmitting power is all utilized in sending the waves in the desired direction instead of all directions. This important advantage, which means reduced cost, will probably not be fully realized because the great ratio of transmission in the desired to undesired directions is probably reduced as the wave spreads out to great distances.

One of the principal means of overcoming interference between the transmissions from simultaneously operating radio stations is obviously the increase of selectivity or narrowing of the band of frequency which each station uses.

We also have the advent of strictly constant-frequency systems. A striking means of accomplishing this is furnished by the piezo-electric oscillator.

*Abstract of a lecture by Dr. J. H. Dellinger, Chief of Radio Laboratory, U. S. Bureau of Standards, before Philadelphia and other local sections of A. I. E. E.

Discussion at Spring Convention

PAPERS ON HYDROELECTRIC POWER DEVELOPMENT

(THURLOW AND SIRNIT[1], BARFOED[2], WHITE[3], ROGERS[4])
BIRMINGHAM, ALA., APRIL 7, 1924

W. S. Lee: Mr. Barfoed's paper, like any one touching on hydro-electrical practise and the whole series of operations on the West Coast, could be divided and make good subjects for forty papers.

I am going to take some exceptions to his arch dam in comparison with the ones in Southern use. It is true this type has developed in California on account of the distance which materials have to be hauled as dams of this design have less cement and material to be transported. In the South I think the gravity section is the proper one to use.

It is not the practise in the South to use dams of this design, and the reason for it is heavy overflow of water.

I would also take exception to the use of the core-wall in earth dams. A core-wall in an earth dam is of absolutely no use. It is not strong enough to hold anything and with a wet blanket of earth on one side and a dry blanket of earth on the other it will move, crack, and leak thereby destroying its only value.

P. M. Downing: Steam plants in the hydro-electric system have for several recent years been in use on the Coast. The length of the transmission lines in the West is generally quite great, and there can be no question that the steam plant is quite essential as an economical factor in handling peak loads.

I don't want the impression to get out that the people on the Coast have the feeling that multiple arch dams are suitable among all kinds of conditions. There are certain places where one or two-arch dams are much more economical than gravity dams. The kinds of dams used are dependent entirely on the conditions. Very few of the dams of the multiple-arch type are ever used where there is heavy run-off; there the gravity type of dam in certainly more desirable. We don't have the heavy run-offs during the whole year; our maximum flows come along in May generally when the snow is melting. Occasionally in winter months, if there is a light snow and a warm rain on top of that snow, there will be quite heavy run-offs; but that is the exception rather than the rule. We do not have the severe conditions to meet there that you have to meet in the streams in the South. So that I say the dams that are selected depend upon the conditions.

Geo. A. Orrok: I am very glad to hear Mr. Downing bring out the fact that where you have a long distance high-tension transmission line it is good practise to run the line at the maximum load all the time.

I have listened to Mr. White and the other gentlemen talk about the pitting. Mr. White pays particular attention to the wearing away of the runner—he calls it pitting; I call it cavitation, but it amounts to the same thing. Cavitation has been one of the most difficult troubles to overcome. I have been told quite frequently that the European manufacturers have learned how to overcome cavitation and that they had no more cavitation. I had occasion last summer to visit Italy and Switzerland, and I was greatly concerned to find in a corner of almost every plant three or four old runners with very marked cavitation. In one plant I found five runners that had been replaced. The old runners had been welded.

It is my own opinion that until a new runner design has been made and tried out in actual service, no one can guarantee that it will not cavitate. In a conversation with Mr. White this morning, he brought out the fact that this might be a chemical action, and that the theory of cavitation which was brought out in connection with the marine propeller is the proper theory. In hydraulic runners it usually is some slight error as malformation or misapplication of the curve of the vane. A vacuum is formed in the wake of the vane where the occluded oxygen of the water may collect. I recollect three runners made from the same set of cores where this cavitation did not occur in the same place. Of the three runners made from one core and put in three separate settings in the same hydro station, one cavitated on the back of the vanes exactly in the center, the second one on the inside of the outside rim, and the third one cavitated near the hub. There have been two other runners made since then from the same box which I understand show signs of cavitation but not in the same place.

When the curve of the vane is changed to meet the condition, the cavitation will cease, and after that you can make any number of runners from that same core and there will be no more trouble.

In making some heat transfer tests, I had occasion to work up a method for testing the amount of the occluded oxygen in water. In this case the water was salt. This method has been adopted as a standard method and I believe it makes a lot of difference whether the water that is flowing through the wheel contains more or less occluded air. In a test on a centrifugal pump several years ago, we got an efficiency of eighty-nine per cent, until we noted a lot of air bubbles in the water and found we had a perfect plant for mixing air with water. The water weighed nearer fifty pounds per cubic foot than sixty-two and a half. That would make some difference in the cavitation as well as efficiency.

P. M. Downing: On many of the plants operating in the West, where we use impulse wheels, we have an action very similar to the cavitation that takes place in the reaction turbines, generally within the buckets on both sides of the splitter. The action there is very similar to the cavitation that takes place in the reaction runner. I would like to ask if there is any close relationship between the causes of pitting in these two different types of wheels?

W. S. Lee: What Mr. White and Mr. Orrok have been discussing takes place on the opposite side of the runner. We have in operation today wheels that have been in operation eighteen years, on which the pitting occurs on the under side of the runner. If it does not cut through, we bore a small hole of ¼ in. in size; this often stops the pitting.

Geo. A. Orrok: Do I understand Mr. Downing to say that the cavitation spots are rough just as though the iron had been dissolved out leaving the graphite of the cast iron showing?

F. M. Nash: I have had to contend with the question of this eating-in or erosion in both impulse and reaction turbines and have found it about as bad in one as in the other. The impulse turbines using a 3 in. nozzle under 1800-ft. head had to have both needle tip and nozzle tip renewed two or three times a year. With the reaction turbines, we had considerable pitting on the back side and near the outer edge of each runner vane, just as Mr. White says, but the worst wear occurred on the clearance rings of a 500-hp. horizontal double-runner reaction turbine under 340-ft. head. This ring was of cast iron and the erosion destroyed the clearance-ring metal for a depth of 1 in. and more in a radial direction. This caused a very ragged and deeply pitted condition that had to be repaired. Repairs were made by dismantling the turbine, cutting back the clearance ring with torch and chisel for a radial depth of 1 in. or more and then welding in by use of torch a ring made up of 1¼-in. x 2-in. iron to give it something near the original setting. This work was all done in the field and no attempt was made to true it in a lathe. The repairs proved to be fairly satisfactory.

All the pitting was considered to be due to chemical action of

1. A. I. E. E. JOURNAL, Vol. XLIII, August, p. 719.
2. A. I. E. E. JOURNAL, Vol. XLIII, July, p. 641.
3. A. I. E. E. JOURNAL, Vol. XLIII, June, p. 519.
4. A. I. E. E. JOURNAL, Vol. XLIII, December, p.

the particles of air on the iron under a slight vacuum, and not due to the wear of either water or sand and silt. Furthermore, all the pitting of this kind that I have had occasion to observe has always occurred in water wheels or turbines under a relatively high head. Under heads of from 20 to 40 ft. even though the water is heavy with silt the year around, I have never known this pitting to occur.

W. F. Dawson: One would be rash, after noting the serious troubles still experienced with cavitation to claim an immediate remedy, but I am strongly of the opinion that marked improvement could be secured if these parts could be chilled-cast, or at any rate, chilled about those surfaces where electrolysis, due to cavitation, is expected. Many of these runners are cast in manganese "bronze" or more properly manganese brass, which contains approximately 45 per cent of zinc. Zinc has a strong tendency to segregate, particularly when poured in ordinary sand moulds, but if the moulds are lined with chills of thicknesses, say equal to one or two times the thickness of the casting, the segregation is prevented and a clean casting of uniform grain structure is thereby obtained. Chilled castings not only prevent the segregation of the zinc and other materials in the alloy, but also makes a stronger and tougher casting. The elastic limit is frequently raised 30 per cent and I have seen cases where the elongation was increased from 2 to 3 per cent to 10-15 per cent.

While I have not had actual experience with chilled iron castings, I believe that this material can also be chilled to advantage, but in that case the material would have to be carefully annealed after casting.

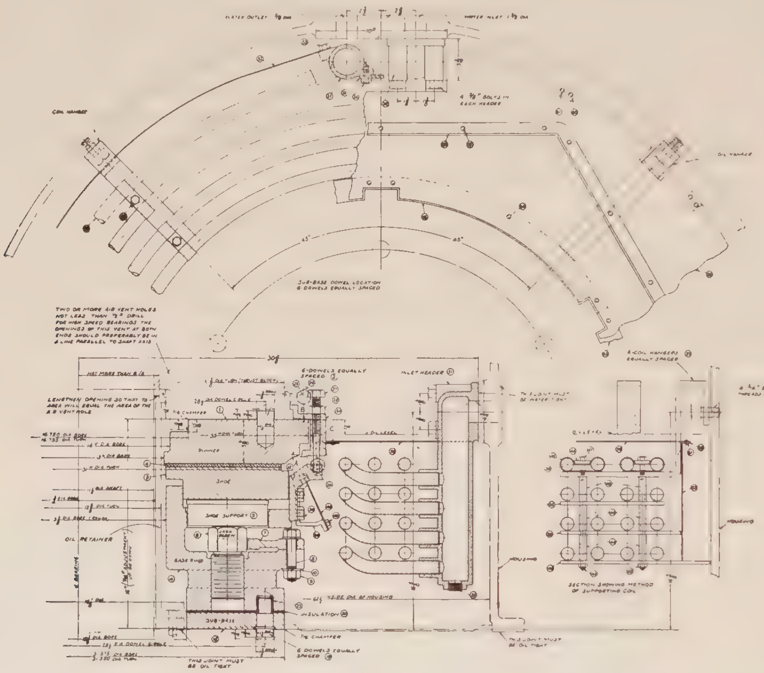
It is fairly well known, but should be continuously emphasized, that corrosion occurs due to electro-chemical action between elements separated from each other in the electro-chemical series whenever an electrolyte is present. If the chilled casting or any substitute process maintains a perfect chemical combination of the elements, the tendency to corrode is greatly reduced as compared with those castings in which the elements are segregated.

Geo. A. Orrok: I have never had the opportunity of seeing an impulse turbine bucket that was cavitated. If you take cast iron and put it under a magnifying glass, you can pick out the cast-iron crystals; the carbon standing up by itself, and you can take your knife and pick the graphite out of the cast iron. In cast steel you get that same thing, but certainly the harder crystals of the cast steel stand better while the softer ones are dissolved out by oxygen.

I would like to say one thing with regard to this chilled iron. I have seen chilled iron buckets which cavitated in the same way. I don't know what has been done with manganese bronze, but steel plate buckets cavitate in the same way when the curves are not right.

Arthur B. Lakey (by letter): The author has mentioned that the entire rotating weight of his generator, exceeding 700,000 lb., was carried by the Kingsbury thrust bearing. This figure, however, is far short of the total thrust load. When hydraulic load and revolving weights of generator and turbine are all included, the load on each thrust bearing reaches a total of 1,250,000 pounds, the highest bearing load on record.

The first of the three Kingsbury thrust bearings for these 65,000-kv-a. units went into service with the General Electric—I. P. Morris unit on December 18, 1923.



THRUST BEARING FOR 70,000-H. P. GENERATORS

Each of the three 70,000-h. p. Units of the Niagara Falls Power Co. uses a 69-in. Kingsbury bearing, illustrated above, which carries 1,250,000 lb. load at 107 r. v. per min.

The illustration shows the distinctive features of the bearings which has a diameter of 69 in. across the babbitted faces of the pivoted segments. The unit bearing pressure is 483 lb. per square inch of the net surface of the segments. At the normal speed of operation, 107 rev. per min. the thrust bearing friction loss per unit is about 45 h. p. or 1/16 of 1 per cent of the unit's rated output.

Certain design features of these Niagara thrust bearings are deserving of comment. Although an oil-circulating system is available, the thrust bearing in the first unit has been running to date without connection to it. This is possible because of the high efficiency of the water cooling coil. The inevitable agitation of the oil by the thrust-bearing runner, below the top baffle, is utilized to secure this result.

The virtual elimination of loss of oil results from the use of the air-seal ring in conjunction with the baffle plates around the coil. This ring, which is shown in the illustration, keeps air out of the oil bath and films, thus increasing the bearing's factor

of safety. The free surface of the oil is protected from all disturbances. Consequently evaporation losses and oxidation of the oil are reduced to a minimum. Their formation being prevented, oil spray and oily mist are kept out of the electrical windings.

With this unit operating normally, an inspection of the bath through the windows provided shows that the oil is clear and solid, holding no air in suspension; also that in spite of the high rim speed at which the bearing operates, the free oil surface is to all appearances as smooth and free from bubbles as during a prolonged shut-down.

The type of bearing equipment described, with cooling coils and air seals included, is virtually standard on recent important medium-speed and high-speed vertical work. In most of these installations no oil circulation is used for the thrust bearings.

When assembling this 65,000 kv-a. Niagara unit the jack screws supporting the Kingsbury shoes were utilized to lift the rotor from the blocks and to adjust its height to secure the proper vertical clearance in the turbine. The screws proved much more convenient for this purpose than the station cranes.

The illustration shows the insulation which, also in line with Mr. Kingsbury's recent practise, was included in the Niagara thrust bearings as a protection against possible damage from shaft current.

Later in his paper, Mr. White mentions several other developments using turbines with Francis and high-speed runners. All these units use Kingsbury bearings, mostly fitted with cooling coils and largely employing air-seal rings.

The entirely successful performance of the unit already operating at Niagara under the previously unheard-of load of 1,250,000 lb. has strengthened the conviction that thrust bearings are no longer a limiting factor in hydroelectric design. In fact, a generator has already been projected in which the estimated thrust load is to be 1,600,000 lb. When constructed this giant bearing will not represent any greater relative step in advance than the Niagara bearing which has already proved itself in service.

F. H. Rogers: The various points raised by Mr. Mitchell and others are of considerable interest, as they bring out a method of operation in a hydroelectric station which the writer believes has been in more or less general use, but which unquestionably is in error. That is, in most stations where three or four units are installed, it seems to be the general impression that the most economical method of operating these units is to run as many of the units as possible at their points of best efficiency and to take up the balance of the load by running one or two units at a considerably reduced load.

Without studying this matter carefully, it might appear that this method of operation would be the best as most of the units in the station would be running at their maximum efficiency. However, the fallacy of this is very fully proven and is shown clearly diagrammatically in Fig. 29. The point at issue is that although the majority of units which are run at their best efficiency are certainly developing power in the most economical method, the remaining unit or two, as the case may be, which are running at part load, are running so inefficiently that this loss more than balances the gain in the units operated at their best efficiency, and that the most economical results, taking the plant as a whole, follow when all units are run at the same value of the differential curves showing the rate of gain in power to increase in discharge.

It might be pointed out that the particular examples shown in the paper in Fig. 29 are for units operating under the same head, although these units are of different characteristics and of different size. The general theorem, however, applies to units operating under different heads and in different stations, provided that we are interested in the maximum total output of all the plants in kilowatts for a given total quantity of water discharged through all of the plants.

It might further be pointed out with interest that the curves shown in Fig. 29 are plotted for a constant effective head on the turbine for all flows. In reality, however, in any given station, the effective head on the turbine decreases as the load is increased due to the greater friction loss through the intakes and penstock. If this point were taken care of in plotting the curves in Fig. 29, the power output Curves C_1 and C_2 would bend down more rapidly as the quantity increased and this, of course, would have the effect of bending down the differential Curves A_1 and A_2 more rapidly as the quantity increased. These differential curves show very clearly the inadvisability from an efficiency viewpoint, of running any hydraulic turbine appreciably beyond its best efficiency point, for it can be seen from the differential curves that the gain in power which is equal to the area under the differential curves, rapidly decreases as the load is increased beyond the best efficiency point. In most plants, therefore, when water economy is of importance, it is now considered advisable after making an efficiency test on the unit, to block the turbine gates definitely at a point slightly beyond the maximum efficiency, so as to prevent the operators running the machines beyond this point where the economy is falling off at so rapid a rate.

S. Barfoed: Construction of hydroelectric undertakings is very much influenced by natural conditions. Therefore, structures selected for one location will seldom fit in another. One cannot favor certain types. But it is an engineer's duty to be fully informed about economical methods and structures, so that he can give the public the benefit of saved capital in the use of them. It is obvious that no structure should be chosen for a site where it does not fit or where suitable materials can only be had at great cost.

On southern streams, of which Mr. Lee speaks, no doubt he is right to choose the gravity type. A multiple-arch dam is not an overflow dam, but a single-arch dam properly designed is. Apparently the canyons of southern streams are not of the shape which will at all permit consideration of the single-arch dam. In the west many streams flow in canyons of ideal shape for such dams. A saving in capital expenditure results and the structure has at the same time a much higher factor of safety than a gravity dam.

Earth dams are by no means standardized. With previous foundations of great depth, the corewall is a successful item in their construction.

LIGHTNING ARRESTER TESTS[1]

(Young)

Birmingham, Ala., April 8, 1924

E. E. F. Creighton: It seems to me that Mr. Young's tests are in the direction to satisfy the users of lightning arresters. The users have felt for some years the need of tests aside from those of the manufacturers, developers, and designers of lightning arresters. It is important to recognize the limitations of the tests as carried on outside of a thoroughly equipped laboratory. On one hand there is the possibility of separating the sheep from the goats. There are on the market types of lightning arresters which are really not dischargers at all and have no particular value. The operator should be able with his tests to separate arresters of good discharge rate from those that have practically no discharge rate.

On the other hand, I hold out no hope at the present time that the operators will so refine their methods of tests as to distinguish between types of lightning arresters all of which have a reasonable discharge rate. It is not yet possible, by any method we know, to distinguish fine differences between lightning arresters. There are no casual tests of a few days' duration that I would accept to take the place of a year of tests involving hundreds of thousands of discharges under as many varied conditions as we can devise. May I repeat that these statements have

1. A. I. E. E. Journal, Vol. XLIII, December, p.

nothing to do with the work that Mr. Young has done, because the value of his tests is to show whether an arrester has a sufficient discharge rate to take off lightning or not.

K. B. McEachron: For many years the large manufacturing companies have been making tests on lightning arresters of various types in order to ascertain as nearly as possible how the different arresters compare in characteristics. To do this, use has been made of the discharge of condensers through the arresters under test. Different values of capacity and voltage have been used by the different investigators to represent as well as may be, the duty an arrester would be expected to perform in service. Although no agreement has been reached among the several investigators as to the proper values of the constants to be used, all appear to be agreed that the use of a discharge of this general type is proper for the determination of the instantaneous voltage across an arrester. Such a test determines only the peak value of the discharge and does not give any information as to how long such peak voltages continue. Very often lower voltages longer applied will cause more damage than higher peak voltages of much shorter duration. Peak voltages as measured by sphere gaps tell only a part of the story, and thus comparisons based on such tests only partially determine the relative protective values. Of course the value of the instantaneous voltage with any particular arrester tested will depend not only on the arrester but on the constants of the circuits used. This is true because in general the wave fronts developed by different impulse generators will differ, and as a result the same arrester will discharge at different voltages depending on the speed of operation of the arrester.

With a certain wave front, tests made on different arresters as reported in this paper by Mr. Young are comparable, although it should be remembered that changes in wave front will affect different arresters differently.

To be of greatest value the report of a test of this character should give more details than given, concerning the conduct of the test, and the exact nature of the apparatus used when tested. Such data will aid in making comparisons with other tests made elsewhere.

Since much of the value of the arrester is based on the instantaneous voltage across the arrester when small currents are flowing, and on its ability to discharge large currents without excessive rise in voltage the measurements given by Mr. Young in Table I are important.

With every arrester tested, except the electrolytic, the voltage across the arrester was found to be nearly equal and in some cases more than the applied voltage. In addition voltages are also observed across the series resistance which in some instances are also equal to the applied voltage. This is a condition which does not tend to inspire confidence in the test results. By referring to Fig. 2 which is the connection diagram for the impulse test, an explanation for some of the variations in test results may be found. Presumably the gap called the voltage measuring gap was set for either 100 or 150 kv. as the case might be. The actual condenser voltage was higher than the setting of the gap by an unknown amount depending on the arrester in circuit. This is true because the arrester with its gap is in series with the main measuring gap, and the voltage across each gap will depend upon the relative capacity of the two gaps in series. In order that the voltage across the condenser be correct, a high-resistance water tube should have been placed across the arrester and its gap.

There are certain details of test which effect the results considerably, for instance when reading the gap across the series resistance, the gap in parallel with the arrester should be opened to prevent sparking and vice versa It is assumed that such precautions were taken. The nature of the series resistance is important in that its resistance must be constant at all frequencies. The water tube is the most satisfactory resistance.

It has been my experience in taking a large number of impulse volt-ampere curves with as small a physical circuit as possible, that the sum of the instantaneous voltages across the arrester and the series water tubes was approximately equal to the applied impulse. Cases have arisen due to reflections, oscillations, or other causes, where this approximate equality was not attained.

It is difficult to draw conclusions based on the data given in Table I because of the apparent lack of agreement in the results. This condition is well illustrated in the case of arrester No. 4. This arrester is a type which should have constant resistance instead of being reduced from 1100 to 520 ohms when the series resistance was reduced from 27 to 90 ohms.

To secure the best comparison it is desirable to make tests on as large a group of arresters as possible to determine the variations between arresters of the same type. Great care should also be taken in making the tests to obtain the most accurate results possible.

The results of tests given in Table II are interesting and are, perhaps, more comparable than those given in Table I. Although the condenser voltage is not given, it is probable, as the author states, that the test made without any series resistance represents a condition more severe than would be met in practise. Such a discharge may well equal 10,000 amperes or more, the actual value of course depending on the arrester resistance and the circuit constants.

Table III shows the results of dynamic tests. In a test of this character it is very desirable to take oscillograms so that the exact operation of the arrester may be studied. From the standpoint of the effect of the arrester operation on the system, the valve-type arresters have shown themselves to be superior in that little or no dynamic current flows following the condenser discharge.

The simple calculation made to determine the current to be discharged by the 22-kv. arrester assumes that the arrester resistance during discharge is zero which is of course not strictly accurate. This calculation does give a value which indicates the order of magnitude of the maximum current and arrester under the assumed condition should discharge. A more accurate calculation is probably not worth while for the purpose of this paper especially when the actual surge voltage may vary greatly from the assumed value.

It is interesting to note that in spite of differences in detail the conclusions regarding the value of the different types agree in general with tests which we have made. The actual values obtained are in many cases much different, although the agreement is much better for the general tests given in Tables II and III.

The results of the tests on the 4-kv. arresters and the conclusions drawn are interesting. The discussion here given concerning the testing methods applies with equal force to these tests. It should be noted however, that better agreement is found among the results in Table IV than in Table I. Mr. Young concluded that satisfactory protection would be obtained from any of the types which met the test satisfactorily. In general where the density of the arresters is high these conclusions will probably be true. More detailed tests would no doubt have shown more definite differences between various types.

H. G. Brinton (by letter): In Mr. Young's paper, certain calculations of arrester efficiency were made. It was assumed that a surge voltage was applied to two resistances in series. One of these resistances represented the arrester impedance and one represented the surge impedance of the line. The voltage distribution was calculated from Ohm's law. This method is incorrect as the current and voltage relations are not the same as in a circuit involving a true surge impedance which is a factor depending upon the distributed inductance and capacitance of the line. The correct general formulas derived by methods ordinarily used for traveling waves are given in an article by Faccioli and Brinton on "High Frequency Absorbers" in the

"*G. E. Review*" for May 1921. The particular formula for each special case can be obtained from the general formula.

In case the arrester is tapped off a line of uniform surge impedance Z and the arrester impedance is practically a pure resistance R, the ratio of arrester voltage to the voltage of the traveling wave or surge voltage is equal to

$$\frac{2\,R}{2\,R+Z}$$

The arrester voltage is 1/5th the surge voltage when the arrester resistance R is 1/8th the surge impedance. Using the above mentioned incorrect method for this same case, the resistance R is found to be 1/4th the surge impedance instead of 1/8th.

In case the arrester is at the end of the line with a transformer we may assume that the surge impedance of the transformer is about 10 times that of the overhead line and the formula given above is changed to

$$\frac{20\ R}{11\ R+10\,Z}$$

In this case the arrester voltage is 1/5th the surge voltage when R is one ninth (1/9) the surge impedance of the line.

In the case of the aluminum arrester we have to consider the effect of capacitance as well as resistance in the arrester, although the arrester films puncture and short circuit the capacitance if the voltage rises sufficiently. Taking the simpler case of an arrester tapped off a line of uniform surge impedance the general formula for the ratio of arrester voltage to surge voltage (assuming film has not yet punctured) reduces to

$$1-\frac{Z}{2\ R+Z}\,\epsilon^{-\frac{t}{c\,(R+Z/2)}}$$

Assuming that $Z = 300$ and $R = Z/8 = 37.5$ and $C = .033$ m. f. = capacitance of 75 cells in series and further assuming that $t = 1$ micro-second with a wave 1000 feet in length, the magnitude of the above voltage ratio is 0.32. Thus the arrester voltage is about ⅓ instead of $^1/_5$ the surge voltage as it would be if the arrester were a pure resistance. This assumes that the arrester voltage is not high enough to puncture the film. From the formula for condenser voltage it can be calculated that the voltage on the films is about ½ the arrester voltage under the above conditions. After the films puncture the action is that of a pure resistance.

LIGHTNING ARRESTER EXPERIENCE IN CALIFORNIA[1]

(Stauffacher)

Birmingham, Ala., April 8, 1924

E. E. F. Creighton: Mr. Stauffacher's paper is an excellent record of observations. It is the type of paper that builds up and confirms standards of practise. It is of value both to the operators and the manufacturers.

Potentials induced by thunder-clouds are independent of the operating voltages of transmission lines. Under identical conditions of induction a 2300-volt line will have induced on it by lightning as high a voltage as the 220,000-volt line. The insulation strength of the apparatus, however, is widely different. As a result, lightning arresters are not yet applied to the very high voltage lines. But somewhat inversely proportional as the voltage of a circuit is less the number of arresters used is greater.

K. B. McEachron: There are two factors of considerable interest mentioned in the paper. On a system which apparently did not need lightning arresters an extension of the system increased the frequency of trouble to such an extent that the application of lightning arresters became desirable. It is also important to note that the number of troubles increased as the voltage of the system decreased, and consequently the dielectric strength of the insulation decreased. This condition is well brought out in the paper, showing that 98 troubles occurred on the 10-kv. circuits compared with 39 on the 15-kv., and 14 on the 60-kv. lines during the year 1923. The data given show that over a period of three years an average of nine storms occurred per year with an average of 4.6 disturbances per storm. The actual values may, perhaps, be more than this because more disturbances are listed in the first table for 1923 than are given in the second table for the corresponding months.

A valuable feature of the lightning arrester has been mentioned as "an excess voltage deflector," indicating the ability of the arrester to save apparatus in case of accidental contact with a high-potential circuit. The author states that for this purpose alone the use of the arrester is justified on the lower-voltage circuits. This is an important service which an arrester may give even though it is itself damaged or destroyed during the discharge. This feature is often lost sight of in discussing the value of lightning arresters since the attention is usually focused on disturbances due to lightning.

G. H. Middlemiss: Lightning disturbances in this section are particularly frequent during the months of June, July and August. On the system of the Alabama Power Company it is fairly accurate to say that we have a storm somewhere upon our circuits, perhaps every day of those months. In the other three months of the summertime, the storms are less frequent, but in general, we have plenty of lightning.

In connection with Mr. Stauffacher's paper, he mentioned that they had made a change of policy, in that the lightning arresters which were originally installed upon the buses alone at the primary substations and generating plants, and are now being transferred to each line. That policy is very much contrary to the one that we have adopted. In the original construction of our high-voltage 110,000-volt to 44,000-volt transforming substations the lightning arresters were placed upon each incoming 110-kv. line and upon each outgoing 44-kv. line. About three years ago, we changed our ideas, and installed substations with the lightning arresters on the buses only, with the thought of protecting our expensive and valuable transforming equipment and letting the oil breakers take care of themselves.

The operating experience following that change seems to indicate that we have not made any serious mistake in adopting such a policy. Approximately, I don't believe we have had any more failures of apparatus in the substation since the arresters have been installed to protect only the transforming equipment, than we had when the lightning arresters were placed upon each line. In connection with our 44-kv. circuits, we have very few lightning arresters installed, except at the primary substations.

I collected a few figures this morning on transformer failures involving destruction of the coils or breakdown of the insulation in the windings. In 1921, 60 per cent of the coil failures occurred when there was a lightning storm in progress. We don't know whether the failure was a result of the lightning disturbances of the storm or not. In 1922, 30 per cent of the failures occurred during lightning disturbances, and in 1923, 45 per cent of our coil failures occurred during such times.

These figures do not include bushing troubles, flashovers on insulators in the substation, and so on. Of course, we have a great deal of those, and that type of failure constitutes a large number of our interruptions upon 44-kv. circuits.

The unfortunate part of the present discussion is that we do not know exactly what the lightning arrester will do. We have had one 110,000-volt transformer fail, fully protected by lightning arresters, and we have had likewise our 44,000-volt transformers fail in the same way. Most of our 44-kv. transformers are not protected with the arresters, and I can't say definitely as to the percentage of 110-kv. failures as compared with 44-kv. failures, but, considering the number of transformers involved, I do not believe we have had any more failures on the 44-kv. apparatus than we have had on the 110-kv. apparatus whereas the 110-kv. equipment has been fully protected with lightning arresters.

1. A. I. E. E. Journal, Vol. XLIII, July, p. 660.

J. S. Jenks: The writer has frequently seen lightning arresters connected in such a manner that the disturbance has to reverse itself, turn very acute angles and follow a circuitous route to and through the arrester and thence to ground. Experience has proven to us that lightning does not do such things and that lightning arresters do not have any special attraction for lightning, but that the simplest form of arrester will pass lightning readily if the lightning is led to the arrester. For instance; as the West Penn Power Substations were originally built the incoming line wires were connected to the bus bar direct; outgoing lines and transformers through breakers. The lightning arresters were connected to the bus bar promiscuously with the result that transformers were being destroyed at every lightning storm and the lightning arresters were not even discharging. In many cases lightning passed by the lightning-arrester tap to the bus bars and went to ground through the transformers.

This led the speaker to believe that the lightning disturbances were following the path of the current, as laboratory tests proved that the lightning arresters would break down at about one-half the potential at which the transformers would break down, and it appeared that if the lightning were led to the arrester directly rather than to the transformers it would go to ground over the arresters and not disturb the transformers. Hence the stations were wired, bringing the line wires straight into the arresters and then making a connection from the arrester to the bus in such a manner that the lightning disturbance would be led to the arrester over a line having very easy curves and no sharp angles, while the lead from the arrester to the bus parallels directly back near the wire of the incoming lead for a distance and then proceeds to the bus in the most convenient manner.

This made it necessary for lightning to get to the bus bar to come directly into the lightning arrester and then reverse on itself and go back to the bus over a conductor on the same field as the incoming lead. After this change was made the trouble immediately transferred from the transformers to the lightning arresters and the arresters began to perform the function for which they were intended, and while they did at times burn up, it was a simple matter to disconnect them from the line and continue to give service. On the strength of this experience we have consistently made all our high-voltage lightning-arrester installations in this manner except in a vew few cases where the work was under the jurisdiction of consulting engineers to whom we could not sell the idea, and they in several instances made lightning arrester installations in other ways, with the result that apparatus suffered and we eventually had to change the installation, which in every case has eliminated the trouble. Hence we are of the opinion that it is more essential to lead the disturbance to the arrester than it is to install choke coils.

E. R. Stauffacher: As stated in the paper, it has been the experience of the Southern California Edison Company that the lightning arrester is a valuable piece of protective apparatus, not only from the standpoint of protecting against atmospheric disturbances, but from the standpoint of protecting against excess voltages due to lines of different operating voltages coming into accidental contact with each other. This latter service places the arrester in the category of an excess-voltage deflector and in this capacity it is most valuable at all times.

Experience has shown that apparently greater results are achieved from a protective standpoint by having comparatively inexpensive lightning arresters connected to each of the outgoing lines from the substation rather than having more expensive types connected to the bus of the substation. This does not agree with the practise of the Alabama Power Company, but it appears that in the case of the Southern California Edison Company the use of an arrester exclusively on the bus does not give all of the protection desired.

The use of lightning arresters apparently is more justifiable in the case of lower voltage circuits, that is, 2.2 kv. to 60 kv. rather than on the higher transmission circuits of 70 kv. and above.

NEW TYPE OF HIGH TENSION NETWORK[1]

(Thomas)

Birmingham, Ala., April 8, 1924

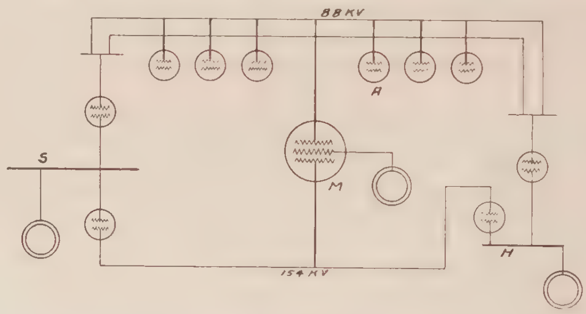
and Worcester, Mass. June 4, 1924.

Robert Treat: Those who have had occasion to try to calculate the division of current in parallel high-voltage and low-voltage lines, will have great admiration for Mr. Thomas' courage in undertaking the solution of a problem of the magnitude of this one. Those who have not been brought in contact with such computations, probably have very little conception of the difficulty of the task.

Some time ago, in our office, we were faced with a similar problem, except that it was very simple compared with the one which Mr. Thomas has undertaken to solve. A brief description of the problem and some of the important things we learned in working it out, will be of interest.

Referring to cut herewith a large source of power S, supplies a double-circuit 88,000-volt transmission line from which are distributed a number of variable loads. At the far end of the line, there is connected a hydro-station H, whose available capacity varies from full load to nothing. In parallel with the 88-kv. lines, is a 154-kv. transmission line running from H to S. There is one other connection between the 154 kv. and the 88-kv. systems at a point M near the middle of the transmission, which is made through a three-winding transformer bank.

It was required to determine under certain limiting conditions of load and with different amounts of power available from H,



Transmission Network

154,000 and 88,000 volt systems constituting two loops having one part in common.

the variation in voltage on each of the substation buses. In order to calculate this voltage variation, it was first necessary to know the division of the power and wattless current in the system. The manner of procedure was as follows. An assumption was made that the load at a certain substation A came partly from M and partly from H. Calculations were then made step-by-step on the 88-kv. system from A to H; and then through the three-winding transformers, and the 154-kv. line to H, to see whether the voltages on the low-tension bus at H arrived at by the two calculations were the same.

It was soon apparent that mere equality of the magnitude of these voltages was not sufficient, that they must also be in phase, naturally, because they were the same bus voltage. So it was necessary to keep track of the phase angles of the voltages during each step of the computation, *i. e.*, we assumed a certain load on the lines adjacent to A toward H, and calculated the drop to the next substation. At this substation it was necessary not only to determine the amount and power factor of the current transmitted toward A, but also to know the phase angle of its bus voltage with reference to the voltage on the bus at A. This process had to be carried out through each step of the way to the low-voltage bus at H; then similar calculations were carried out through the other portion of the loop, A-M-H. Obviously, the criterion of the correct assumption as to the distribution of load and wattless in the two systems, was that the voltage on the

1. A. I. E. E. Journal, Vol. XLIII, July, p. 610.

low-tension bus at H when calculated over the two sides of the loop, came out the same both in magnitude and in phase.

It was also necessary to carry out the same process in the loop formed by Stations M and S, and sometimes, it was found that assumptions which appeared to give satisfactory results in one of the loops, were not right when we considered the other. This was because the two loops had one part in common, the three-winding transformers at M. Sometimes it was necessary to make the computations for one set of conditions several times, before arriving at an estimate of load division sufficiently close for the purpose.

One of the interesting things which we found out from these calculations was that the 88-kv. line from H was carrying about twice as much load as the 154-kv. line. This was undoubtedly because of the higher reactance in the 154-kv. transformers at H and M as compared with the lower voltage single transformation in the bank at H. The losses in the 154-kv. line were low, it is true, but there was some question as to whether, with the very small load which it was carrying, its investment was justified; whether it also might not properly be an 88-kv. line, and, therefore, less expensive, and for the particular conditions which we were investigating, carry more power. In the example investigated, the justification for the higher voltage line is found in future conditions which operate to increase its loading.

It was also found that with no regulators or tap-changing equipment in the system, it was impossible to change the distribution of power current and wattless current over the two circuits of different voltage; they were fixed, once and for all, by the circuit constants. In order to get more wattless current to flow in either system, it was necessary to be able in some manner, to secure the effect of changing a transformer tap, thus changing the apparent voltages of the two systems which are tied together through the transformer, thereby shifting the wattless. A shift in the wattless also changes the angle of the voltage drop in the two circuits; thereby the actual load in the two circuits is also changed somewhat, but the two components, power and wattless, are both changed with only that means of adjustment, *i. e.*, by transformer taps there is no independent control of power and wattless.

In order to get more power current to flow in the150-kv. line, it would be necessary in some way to introduce a phase shift in the voltage similar to the phase shift which is inherent in a three-phase regulator. That would shift the distribution of power current between the two circuits, which in turn, would change the voltage drops, thus affecting the distribution of wattless current to some extent. Here, again, it is seen that it is impossible to change the power current without, at the same time, changing the wattless current.

Complete control over the division of power current between the two circuits, and the independent control of the division of wattless current, demands some means of independently varying both the magnitude and the vector angles of the voltages applied to the two circuits; *i. e.*, it is necessary to secure independently, the effect of a phase shift, as by a three-phase regulator, and the effect of changing transformer taps.

This whole question, of course, has very many factors, and as Mr. Thomas suggests in his paper, it requires much further study. I agree with him that it should be fully analyzed from all possible angles, in order that as much as possible may be learned about the problem before attempts are made to carry out the program which he suggests.

W. S. Lee: Mr. Thomas deserves the appreciation of transmission engineers and the power companies at large for this study. It is impossible for Mr. Thomas or any other man to take a system or a group of transmission systems and lay down on a sheet of paper, transmission lines that will fit all the conditions. That can't be done. Unfortunately, load will come at some unexpected place; power plants may be developed at one point or another, and they, of course, must be coordinated in his system of transmission lines. His paper does give us a great deal of food for thought, in that we should continually study the possibilities of connecting all these companies together.

H. Cole: I think there are a number of important problems which have to be worked out in connection with the tying together of large transmission systems. It has seemed to me that some sort of tap-changing transformer or other device which would allow different voltages to be carried on either side of the point of interconnection would be very useful.

H. L. Wills: What is the use of considering these interconnected networks as individual propositions? The only reason we use a synchronous condenser or some method of that kind for holding down the voltage rise is because we haven't enough of that system. If we had that system so big that it was practically one plate, it wouldn't matter where we put our power into it, we would have the same thing as one plate of a condenser—and that is what you are working to, according to my notion.

W. E. Mitchell: From an operating standpoint this problem is not quite as simple—while it works and we have been working it very satisfactory for the past two years—as it might appear to be. The problem of regulation, to push the power whichever way you want it to go, is not so difficult. We had a good deal of trouble in the beginning getting the governors in the different systems to a speed of control that was more or less similar for the load changes in each system, so that with a swing in load, no particular system would try to pick it all up. The result was, from that standpoint, that we were able to carry through from our system over to the east of us, and they were able to pass on farther to the east, loads of 30,000 to 35,000 kw. without any serious trouble. Strangely enough, our troubles all came at night-time when the loads became lighter and when we were trying to keep steam plants here loaded up and the hydraulic plants just floating in for regulation purposes. Under those conditions, we found that the swings were very much greater and that unless the governors had been carefully set and readjusted at night-time the swings of load instead of going 20,000 eastward, we would find we were getting 10,000 coming westward when we didn't want it at all.

But that isn't as bad as the other problem, the problem of voltage regulation and the loading of the wattless current onto the one who is trying to give the power. You come in to help a gentleman out of his troubles, and he promptly doubles the burden on you and doesn't take anything away from you at the same time. Now that, we have found, is serious, and that is a question entirely of voltage.

That can't be controlled, so far as I can see, at the generating plants alone. It has to be controlled at the load centers, and, as far as we can see on our system today, that necessitates condensers.

We are studying our system; Mr. Lee is studying his system; Mr. Edgar is studying his system, looking forward ten years, and when we look forward ten years, we double our present loads. So there is nothing extravagant in Mr. Thomas' suggestion here. If anything, it is too conservative in the quantities considered.

H. S. Fitch: It is not at all simple to adjust plant frequencies so that the load may be distributed as desired. The first point is to adjust the settings of all governors repeatedly until there is obtained an easy fluctuation of load on the least efficient plant, and base load which is constant probably throughout the whole twenty-four hours in the day on the most efficient plant.

The next thing to solve is the wattless current. On our system, by means of penalizing the consumer, forcing him to pay a higher rate for poor power factor, we do obtain some help by having him install synchronous apparatus, but our problem has been met more generally by spotting synchronous condensers at the low-voltage points on the system. We have had to come to the point at the less efficient power stations of disconnecting the turbines from the generators, to take care of this wattless.

The third point is the relay problem. Any interconnected system on which there is a great amount of network must have a relay system which will function so that if one plant is shut down, the load is transferred from that section; in other words, if line trouble occurs between plants and they separate one from another, are the plants unequally loaded so that you are forced to transfer loads by dropping them? Or, again, if you are forced to shut down during the hours of the night or on Sunday, will a condition be created whereby the load must be interrupted again to transfer it to the plants which are running? These problems on relays are large ones and require a great deal of thought on the subject of interconnected networks.

F. M. Nash: I think I can give an illustration of what sometimes happens when you have a long line and try to get two hydro-electric generating stations on the opposite ends of the line to parallel successfully. The bigger station of 10,000 kw. in this particular instance, after a case of trouble, was allowed to charge the line. Then the smaller station at the extreme opposite end of the system was synchronized before any load was taken on anywhere. This was done two or three different times, and in each instance when the lower station had synchronized there began, very shortly afterwards a slow oscillation on the meters that gradually increased to such a point that the two stations would go out of step. It was an urgent condition and the only way we got the plants operating again in parallel was to get the large plant to charge the line, then pick up a large synchronous motor load near the center of the line, and then synchronize the smaller plant.

As the present-day tendency is in the direction of still longer lines and higher voltages, this particular incident is to my mind splendid evidence of the necessity of using synchronous motors or synchronous machines of some kind to hold the high-tension net works together and maintain satisfactory operating conditions in the generating stations.

Howard A. Stanley: There has been one point made which I think perhaps needs a little attention. On Page 12 of Mr. Thomas' paper, he says: "The segregation of a single link is simplified because with the wide separation of power houses and the absence of large concentrated loads, no short circuit can occur in the network of a magnitude to exceed the safe capacity of oil breakers." That is about all there is, I think, in the paper on the question of short circuits.

I wonder if in this network we are not trying to accomplish two mutually conflicting objects. No matter how much reactance you may have, it is entirely possible to have a greater concentration of kv-a. in a short circuit a hundred miles from the generating station than at the station itself.

We have, in Fall River, a network which compared with what we are talking of here is something in the nature of a toy, 23,000 volts—serving approximately 30,000 kv-a. at the present time. It actually works out, in our network, that short circuits remote from the stations are more severe than those at the station.

W. A. Moore: I am speaking from the viewpoint of a manufacturer taking a large block of power.

You said that you would regulate the voltage at a substation by changing the fields possibly in the nearest generating station. That is a problem we are struggling with today on a smaller scale. We are trying to hold a certain voltage condition. I am wondering just how often you would have to change the fields, that is, would you change them at seven o'clock in the morning, at noon time and at night? Or do you find that for actual operation you would have to keep a man on the board, varying the fields every five or ten minutes just to compensate as people 'phone in and tell you that the load at a certain place has changed?

P. H. Thomas: Use an automatic voltage regulator at the generating station. The nearest power house would be the place to do it.

I would like to say here that the advantage that is gained by this particular scheme is that the total transmission, the total amount of power handled by the high tension is overwhelmingly large with regard to any particular station. You have a 220-kv. line 100 miles long between two stations. No local load you can take off the middle of that will affect that voltage so you will notice it. By having a big thing dominate the whole, the variation produced by the local users doesn't amount to anything. If the voltage of this system is regulated every 100 or 150 miles, that is all that is necessary. It wouldn't vary more than half a per cent. from any load you take off in between. The voltage control should be automatic. If the voltage is maintained constant by voltage regulators in the general stations, regulation generator that takes care of itself.

Mr. Moore: That leads to another question. Suppose this sub-station is big enough to have some regulating equipment. Then you would, at times of light load, lower the power factor purposely so as to get the voltage drop.

At the present time here in New England some of the power contracts call for a certain average power factor, and you get a bonus or get penalized, depending on that average. At the time of low load and you lower the power factor purposely, then where the wattless energy is read on a reactor meter, a large reading of wattless power is recorded, and this in turn penalizes you.

C. R. Oliver: It depends upon whether you are trying to maintain the voltage or improve your power factor. If you have a contract like that, let the power company regulate the voltage.

L. W. W. Morrow: The big question in regard to the scheme proposed by Mr. Thomas is "Will it increase service reliability and decrease the cost of installation?"

The long-line bulk-power transmission line has been installed in several instances and its problems have been solved very successfully by using synchronous condensers. But instead of this method Mr. Thomas makes a proposed equivalent to taking power from Niagara Falls and sending it through an interconnected network in multiple to the loads in the New York district. It is a question as to whether this proposal is a better economic and operating proposition than the heretofore used bulk power line having no intervening loads. Under abnormal conditions for example a short circuit on one of the light load taps of the network system might interrupt service to heavy load points and introduce more chances for service trouble than occur on the long line system having no intervening taps between the source and the load.

Then as regards the cost of installation it would seem that the use of single circuit multiple link lines would result in a cost comparable to that incurred in building bulk power double circuit lines because greater mileage is involved in the network system. And, although power factor and regulation are worked out satisfactorily on the network proposed by Mr. Thomas without using synchronous condensers it is a question as to whether this investment could be avoided in the general case.

Another element involves the question of voltage regulation under abnormal and normal conditions of load in a large territory. Mr. Thomas has several fixed but different values of voltage at several locations in the network which retain practically constant values for changing loads under the conditions he assumes. But experience with large networks indicates a continual shifting of loads on the system, the necessity to change the sources of power to conform to water, fuel, and load conditions and the necessity to handle troubled parts of the system quickly and easily. Under these conditions it would seem difficult if not impossible to retain constant voltage values at the different load points on the system. Apparatus are not yet developed to automatically give a wide range of voltage at a substation nor have operating facilities been developed to a degree which will permit a load dispatcher to control excitation, governing and transformer ratios at multiple points on a system in a very short time.

Then again experience indicates that the satisfactory operation of an interconnected system requires that each system in the network have the same standards of construction, service and insulation. This condition is seldom found and there would seem to be difficulties in instituting the type of system proposed in territories now occupied unless this condition was fulfilled.

These points are brought up in connection with this notable paper only as points apt to be raised by engineers more accustomed to the old methods and I am sure Mr. Thomas can answer them.

J. C. Damon: Mr. Thomas presents a pioneer system as regards voltage and extent, but some of the advantages of this network over a trunk line system have been practised.

The West Penn Power Company has a 22,000-volt distribution network which if mapped to an enlarged scale would be similar to that presented and the experience of this system largely bears out what Mr. Thomas expects in economy of lines to reach customers and the ability to feed in both directions to the customer. Relaying such a network has been very difficult but recent developments are solving the problem.

Another question discussed is being demonstrated right on the systems shown on Mr. Thomas' map. The ring of transmission lines shown on the southern portion of the map has been closed within the last few weeks by a new connection between the Alabama Power Company, and the Columbus Electric & Power Company, and the existing connections between the Columbus Electric & Power Company, Georgia Railway & Power Company and the Alabama Power Company. Before the closing connection was made, an investigation showed that the power stations around that ring could control the voltage, as well as the flow of power and wattless current between companies, within commercial limits without any new synchronous condensers. One assumption differed from those made by Mr. Thomas. That assumption is that, knowing beforehand when the light-load periods come, the station voltages can be lowered somewhat to avoid the necessity of drawing heavy lagging current to hold down the voltage over these lightload periods.

F. L. Hunt: The problem that Mr. Thomas has worked out, is, of course, one that we must all solve. We are facing it now, and we have attempted, to some extent, to solve it along the line of economics. It seems to me the solution must be economically sound.

I noticed in one place Mr. Thomas suggested that the system of operation must be worked out only with regard to the whole, regardless of how it might effect one company. Such a plan would be difficult to work out in practise.

Mr. Thomas, in the case which he has assumed, has allowed 100 per cent growth on each sub-station, and, states that the network should be laid out with that assumption to take care of the future conditions. It seems to me that is a little optimistic. They don't always grow so evenly as that, and if you map out a big network on that basis and then the growth is entirely different, the result is not so good as pictured.

C. E. Skinner: Mr. Thomas' scheme presents one rather serious objection from the standpoint of the manufacturers of transformers. This is on account of the very large number of voltages varying by small steps from 190 kv. to over 200 kv. Either the transformers must be provided with a considerable number of taps or transformers in the different stations will not be interchangeable. Interchangeability of transformers is, of course, very desirable for such a system.

C. R. Oliver: Looking at the paper purely from an operating man's standpoint, it struck me as unique and radical in some parts, because the results on our system, which is a small interconnected one in this paper. Before I take up the points brought out in the paper, I would like to mention one or two things that Mr. Thomas discussed outside of his paper this morning. One was that by running the generators on the system—it would be possible to eliminate any synchronous condenser apparatus.

Now, our experience here in New England has been probably the same as that of most of the other companies similarly connected. We have a peak load of 140,000 kv-a., and it has been necessary for us to install 47,000 kv-a. of synchronous condensers. That was after we had used all the correcting capacity of the generators, and we had a hard time convincing our financial people that we needed those condensers. And since we have had them running we have had an awful time to get one out of service for ordinary repairs, because the operating people are using them all the time.

I am wondering on this larger system, using the old stations and the old generators designed for probably only 80 per cent factor, how Mr. Thomas was arranging to keep the power factor constant regardless of the flow of current and regardless of the direction and the amount of current. It is something we haven't been able to do on our system in New England.

P. H. Thomas: The power factor wasn't kept constant.

C. R. Oliver: One other point Mr. Thomas mentioned was that the advantage of the loop over the double-line transmission was that the loop would give so much more capacity because of being fed in by both routes. It seems to me as though the loops must be designed of unlimited capacity. A case I had in mind that particularly illustrates the point I want to make is that on your map at Muscle Shoals, where there is 243,000 kv-a. capacity, with a line running east towards Huntsville and a line running south towards Birmingham, Alabama. Now, in case of trouble on the 65-mile line between Muscle Shoals and Huntsville, that single-circuit line would be called on to transmit 226,000 kv-a. 204 miles to get it back up around Chattanooga.

Now, the General Electric and Westinghouse Company, to date, haven't even been able to figure a double line able to carry that power. I am wondering how that would be taken care of unless that water is wasted and the load is supplied from some other station.

I am particularly interested in how Mr. Thomas is going to maintain these various voltages that he has laid out, all the way from 185,000 up to 195,000, with a generating voltage of 220,000. We have light-load conditions; Saturday afternoon conditions; Sunday conditions and night conditions, and I am very curious to find out how that voltage would be maintained unless we had an extensive amount of tap changes on the transformers. I don't see how the system can be worked unless we use synchronous condensers and hold the voltage flat.

The other point that our company is particularly interested in, is his suggestion of multiple conductors. We have been doing quite a lot of studying on the super power transmission line, and our engineers have not been able, to date, to solve this problem, which is the problem of suitably mounting and handling multiple conductors on transmission lines.

In your design of towers, you claim that a 15-foot spacing is ample between conductors. Now, the insulator manufacturers tell us that the length of insulators on 220,000 volts will be at least six feet. With a 15-foot spacing between wires we will have 7½ feet between the wire and steel. The conductor, under extreme wind conditions, will swing out to a 45-degree angle. The clearance then will be less than two feet between the 220,000-volt conductor and the steel. We felt that was too close.

With regard to the method of regulating the voltage all over this loop, particularly the transfer of power, in case of power shortage from the extreme southern portion to the extreme northern portion—I am anxious to find out how you are going to do it. Apparently, it is not going to be so simple, with all of the various power companies connected, to transfer power back and forth unless you have unlimited capacity of line and unlimited capacity of transformers.

The other point I am particularly interested in is regarding the question of costs. You have outlined 2500 miles of single-circuit line at a cost of $8000 per mile, exclusive of right of way. A line which we finished a month ago, which is a super power

line, cost us more than $8000 a mile for material alone, egardless of any labor or right-of-way or anything else.

Your 200 oil circuit breakers, at $4,500,000 would come to $22,000 apiece. The latest quotation we had from the manufacturer, was $30,000. And your figure not only included the oil circuit breakers, but miscellaneous switchgear, outdoor stations, etc. On a recent estimate we made, this came to $75,000 per breaker.

Farley Osgood: Mr. Thomas has shown us, theoretically, what we would like to do. He has heard practical criticisms from the operating men which may alter the results as he shows them in his paper. I do not think this casts any discredit upon the paper, nor do I think we owe any the less to Mr. Thomas for having developed it in the way in which he has, because if he can point out to us the ideal, with our practical field operation we can lead ourselves into the avenues of finding out how the ideal scheme will have to be modified, so Mr. Thomas' work for us, as operators, is truly accomplished.

I think that I can appreciate his paper as much as anybody, because in New Jersey we are working on this same problem ourselves. Fortunately, it does not have to be decided tomorrow, but with this basic information which Mr. Thomas has prepared for us, we are able to save a great deal of time and to point out to ourselves the difficulties that we are likely to get into.

The practical criticisms which you have heard, I would like to concur in, because our experience matches up with the statements which have been made.

There has been some reference made to the voltage regulation and control, and we in our system get a good deal of help, particularly in power factor improvement, by using, whenever it is possible to do so, our idle generators as synchronous condensers. We have developed a fairly quick coupling arrangement, by which the generators can be disconnected from their turbines, and it is our practise to throw our generators on to the line as synchronous condensers whenever the steam end of the unit is to be taken out for repairs for any extended period, say even for longer than a day or two. We have been doing this for a number of years and, if I am not mistaken, we were the first group to establish this as a universal standard practise of operation.

In our northern network of several hundred thousand kilowatts we have many prime-mover elements, the generator ends of which are used as synchronous condensers whenever they can be released for such service, and the improvement in the load carrying capacity of the system will vary from 25 per cent to 50 per cent of the kv-a. rating of any generator thrown on as a synchronous condenser.

There is no reason, where a generator is driven by a water wheel, particularly if it is a horizontal unit and easily uncoupled, why it could not be used in this manner. In a system as outlined by Mr. Thomas this same scheme could be applied, and all the free generators that would naturally be shut down on account of high cost of driving them, could come on the line as synchronous condensers, and the result to the network must be a very considerable benefit.

You men here in New England are studying your problems as they relate to power obtained from the St. Lawrence, and we in New Jersey are most interested in your study, as it is not beyond the possibility that we might participate in that same development should it be carried through the Metropolitan section, including New Jersey, and on through to Philadelphia.

In the matter of fear of coordination of operation, we must not forget that the people who are going to make these interconnections, while they are not all controlled by one holding outfit, at least, are neighbors, and neighbors are supposed to be friendly, and in the electrical fraternity I am glad to say that is very largely true. And if a network can be devised which will give a group lower costs, the fellows who are operating that group are going to go along with the combination and play the game in the best arrangement of load dispatching that may be worked out mutually.

No engineer ever went into a conference at which some fellow in the group did not say something that he did not believe or that he did not like, but generally the conference comes through with a unaminous opinion, and I have not the slightest doubt that that will be the practical outcome of the conferences which will bring about this network operation on an economical basis as soon as it can be set forth properly, physically, to warrant the money that it will cost.

The thing that I fear most is that, as engineers born full of enthusiasm and who seem to develop more each year, we might be too hasty in recommending to our financial people the accomplishment of this problem outlined. So—not in the way of any disparagement, but rather in the way of a note of warning—let us be sure in making our recommendations to our financial people, first, that we are sound and positive in the engineering accomplishment which we are going to get, and second, that we do not make the recommendation before it will pay.

Long transmission lines are all right, but they should not be built before they will pay their way. We have had many discussions on the cost of transmission lines versus cost of transportation of coal, and in most of the studies in our section of the country one hand about washes the other—in fact, it is mostly in favor of the transportation of the coal by freight.

If we have a large investment for a long period, not earning its way, we are going to get into discredit with the people who back us in these schemes. Our duty is to convince the financiers that they must furnish us money far enough ahead of the load to make us sure that we will be ready to take care of it when it comes. Let them figure the cost of carrying the financial burden meanwhile. We, on our part, will be prepared to show them accurately when the load is expected, and that when connected it will pay.

Otherwise, we shall get into ill repute and we shall have difficulty in getting money for the most excellent engineering enterprises which are in front of us, which are the most costly of any which have come before our electrical body thus far, and which are the most important to the industrial and operating men, and which should be gone into carefully, co-operatively, with our financial backers.

P. H. Thomas: Mr. Mitchell has asked why I have been able to secure stabilization of voltage without the use of synchronous condensers.

There were three reasons. The first and most important one is this: I have taken the liberty of establishing the voltage at each point at the value which will be most favorable for this purpose. I have not taken a level-voltage system. There has been a great deal of talk lately about the constant-voltage system, meaning the level-voltage; that is to say, a system in which the voltage is the same at all points. When you have established such a condition,you have committed yourself to a large and unnecessary expense, at least, in any case where the flow of power is predominantly in one direction. In the transfer of 100,000 kw. for 100 mi., there is a natural drop of voltage along that line for that power. If you establish the voltages at the two ends as normal that which gives this natural slope of voltage, you don't need any synchronous condensers; but if you undertake to maintain the voltage at both ends at the same value you must have synchronous condensers at one end, the receiving end. You notice in my set up I have freely adjusted the voltages to the flow of the load. That is the biggest factor in eliminating the necessity for synchronous condensers, and it is a very powerful one.

In the second place, there is no distinction between leading current which you get from a condenser and what you get from a generator. By taking lagging current on the generator stations we reduce the natural voltage drop produced by power coming from the line. I have used the present generators up to 85 per cent lagging factor, where that was necessary to make a favorable power factor for having the power flow across the system. The conditions of this set-up come very close to requiring some

synchronous condensers. A worse power factor load would call for some synchronous condensers, but their capacity would be very much less than you would expect.

As the third feature, I have worked in the new idea of "divided conductors". It isn't entirely new; I proposed the scheme either in 1911 or 1912, but it is new so far as most of you are concerned, I think. Here is a case where that idea is of extreme importance. Instead of using a conductor ⅞ in. in diameter, I use three conductors in parallel of the same total cross-sections, spaced 12 or 15 in. apart to increase the electro static capacity of the line and reduce its reactance. At the limit I think you can get about double the electrostatic capacity with the three conductors that you get in the one, and about half the inductance. The power in this set-up is taken as flowing over a line where the inductance is two-thirds of normal and at the same time the discharging current is 150 per cent of the normal. The result is obviously to reduce greatly the line drop and to help the power factor.

Those three points, taken in this case, eliminate the synchronous condenser. That is the answer to that particular question.

W. S. Lee: What are you going to do with a voltage regulator on one system which tries to halt the whole load?

Mr. Thomas: The voltage regulator only controls the voltage; it won't affect the distribution of load very much. Give a definite case, Mr. Lee.

Mr. Lee: A power station 50 or 60 mi. from a load center, with a capacity of 80,000 kw. in the station, with a voltage regulator on it. When it boosts that load and another load is perhaps 80 miles on the other side, and it is lagging, what is going to happen?

Mr. Thomas: The generator must be big enough to stand the maximum that can come on, that is all. I don't see any complication there. It seems to me the flow of lagging current automatically takes care of itself.

Mr. Lee: Regulation in putting the voltage up means a bigger flow of current, that opens the governor wide. Then that plant goes out of regulation.

Mr. Thomas: A raise in the voltage doesn't change the load on an induction motor materially. The load is the mill.

Mr. Lee: It does on all we handle.

Mr. Thomas: If the voltage regulator keeps the voltage constant, there shouldn't be any change in the load.

Mr. Lee: Certainly; but if the voltage regulation can have this effect I think the regulation does more harm than good.

Mr. Thomas: That is the problem of the governor, I should say.

Mr. Lee. We would take the governors off, to run your system better.

Mr. Thomas: I will venture to say this type of network will work in much better shape than any other form of a regulator system that you can get. I think the problem you speak of is primarily a governor problem.

Mr. Lee: I think it is a governor problem, and I think you want a rather slow-acting governor.

Mr. Thomas: I am not saying it ought to be slow or fast, but that should be decided by whatever governor you use. That doesn't hinge on the character of the network. The governor should not be too sensitive. But the point I would make is that all the governors should be alike, equally sensitive.

With regard to the calculation of the line—there are 62 different transmission lines. The way I got at it was this. I took the map and drew the lines, noted their lengths, and assumed that the drop in any particular line was proportionate to the power that would flow over it. That is not strictly correct, because the power factor is not exactly the same all over the system. However, it varies only a few per cent., and for the purpose of this discussion, it was legitimate to assume, I think, that the drop in any line was proportionate to the length and the power flowing over it.

These lines are all of the same conductor. The size of this conductor was determined by corona and it happened to come out about right for the energy losses.

After establishing the load taken at each station and the power to be supplied from each generator, I made a trial distribution of the current through the network, to see whether the drop in each branch was the same as in other parallel branches. Of course it wasn't, at the first trial.

Then I shifted the values and finally succeeded in getting, by trial, a series of values within about one per cent. checking up, so that the drop between any two points was the same by different routes, taking the drop as the product of the length times the power.

Then I started at the load end, with the known power at any one particular station, and made a guess at what the proper power factor would be, that is, at what field strength the local generator would be operated. That enabled me to calculate the voltage at the other end of that local line. If that were a generating station I would add in the power or subtract the load, make a guess at the right amount of wattless power and work back over the arrangement.

I had to make one or two tries at that, but finally a satisfactory set of values was found. It was, I might say, a case of shrewd guessing. However, each particular line was calculated exactly when the original assumption was made.

In regard to the distribution of power between the steam and hydraulic stations, I would like to say this. It no doubt strikes you all as a tremendously complicated system to operate, but as I have thought it over and as it has grown in my mind—and it is of two or three years' growth—I don't look upon it as a complicated system. It may be a difficult thing to get started, but picture, in your minds, the ordinary Edison direct-current network in a large city like New York or Boston. In many ways those are the simplest things to operate. They are networks. The power distributes as it likes. If they find the cables are getting too heavily loaded at one point they put in another cable, either parallel or feeding to some other substation, and they keep the voltages about right.

Now, as regards the operation of the distribution of power. Supposing we are starting at a time when water is high and hydraulic plants can carry all the load. The water wheels will have automatic governors. Now, if the water goes down, pretty soon there comes a point where there isn't quite enough water to produce a sufficient backing for regulation. You see that the water is perhaps drawing down in the different ponds, and the load dispatcher tells the steam plant to start up and put a machine on the line. A machine is put on the line and probably that machine begins to govern then, and as the water still drops, or the load becomes higher—the governor on the steam machine will open up and take more steam—and as the water drops off more and more they will take off a water wheel, put on a steam machine, and as any interconnected system now distributes the power by the automatic control of the prime-mover governors, so would this system.

As far as any practical interchange of power for synchronizing purposes or distribution of load, is concerned, this network is a perfect connection; that is, the drops are so small they wouldn't prevent interchange of power or prevent the developing of a large syncronizing power.

This ideal is theoretical, but it is the basis on which successful operation rests in all of our systems today, and I don't see any reason why it shouldn't work out in the same way here.

Now, I would like to make this distinction. At the present time there are interconnections in the South. Most of the companies touch one another. But that is, in no sense, comparable with this network. Each one of these systems is a self-sustaining system, or almost self-sustaining. One company may have an outlying sub-station on one side, which touches a line on another system. They make a connection between. If

there is a little surplus power in one or the other, they can pass the power backwards and forwards. But it is limited by the capacity of the individual circuits with which the systems connect and by the fact that those systems are operated for the local power and not for the sake of supplying power to one another. It is like trying to pull a heavy load with a small string. If, however, they are connected firmly together, then the automatic interchange will be complete and it won't be so delicate and won't be so likely to fall apart at any time.

In regard to that voltage regulation, it looks very complicated, but it isn't. Supposing the system is running and we have our power houses; each power house has its power factor; each load has its power factor. We will say the peak of the load is on. The load drops off, and perhaps around Charlotte, Concord, Gastonia, Mount Holly, the voltage will begin to creep up because the load is creeping off and the generators, we will say, are maintaining the same voltage.

As that happens, the voltage regulator, when it feels the voltage rising, will change the field, until it makes a little difference in the power factor, and then your voltage goes back to where it was. Nobody worries about it.

Now, if at midnight you find that these machines are drawing a big lagging load to keep the power factor down at Mount Holly when at Tallulah Falls it is very high, there is no objection to the man at Tallulah Falls lowering his field. It will change his voltage locally, but that won't bother him. Then the voltage regulators at Mount Holly will reverse and change the power factor back to whatever is necessary to keep that voltage.

The control of power factors at all of these stations is absolutely in the hands of the load dispatcher, if he is willing to change the generator field settings in the different places. Any time you lower the voltage at the station, you change the power factor.

I assumed fixed voltages here to convince you that if you wanted to have constant voltage you could do it—that the system permits it—that the theory provides that you can control your voltage. As a matter of fact, if I were operating the system, I wouldn't have exactly constant voltages. I would adjust them. The main load centers I wouldn't allow to shift very much, but in the distant power houses, I would have the voltage shift up and down somewhat, and by such a method as that, you can eliminate such objections raised as to running many light generators at night, etc.

Mr. Osgood made an excellent point with regard to the use of generators as synchronous condensers by cutting off the prime mover. That is really economy. You are getting something for nothing when you do that. The only thing I will say is that in this case you will get an added advantage from that sort of thing where the generators lie in the sub-stations because you correct the power factor at the sub-station and the lower power factor doesn't have to be taken over the high-tension line. In a remote generating station, if that is where your synchronous condenser is located, that merely relieves your other generators of the bad power factor load.

I didn't intend to say very much about the costs, in this paper, and Mr. Oliver isn't the first one to criticize the $8000 per mile as the cost of these circuits. I feel very confident that if Mr. Oliver were given the task of building 2500 mi. of single-circuit line in Alabama and Tennessee, and he had five or ten years in which to do it, and if those lines merely had to do what these lines have to do, he could do it for that price. Remember that conditions will be very, very different. I have taken some actual figures for the cost of towers, etc., and I feel confident that can be done.

Now, of course, there are all kinds of conditions in which work is done. Where conditions are favorable, in foreign countries with better labor conditions, and that sort of thing, that $8000 cost could be bettered. But conditions around here are very different. A man doesn't have a free hand—he can't do as well as he might in other places.

The question was raised at the beginning of the discussion as to how it happened that we could have such large amounts of power transmitted such long distances and when it came to a short circuit not have much, if any, power to handle. Mr. Stanley, I believe, pointed out that it wasn't the case down at Fall River. This is the reason. We are working on a larger scale. We have longer distances here. We have high voltages. Now, you who have studied high-voltages lines, know that a 220-Kv. line will transmit a very large amount of power a long distance if the voltage is maintained. As a result of the reactance of the line you can get a high degree of efficiency because the charging current in that high-voltage line neutralizes the effect of the reactance, and as long as the charging current will neutralize the effect of reactance in that long line, you will get efficient transmission.

But should you get a short circuit so that the voltage is killed at that point, then the reactance is no longer neutralized by the capacity effect, and you are working with a reactance, pure and simple, at least on one end, but the net result is that you are working through a large reactance and the amount of power taken is very small.

Take, for example, a case which I have in mind of a 500-mile transmission at 220-kv.—a very large circuit. You short circuit one end of that with full voltage on the other end and the amount of power from the generator is about 7000 kw., on a circuit which has between 140,000 and 150,000 kw. as a maximum load.

Most of the jumps between stations in this set-up are 20, 30, 40 and 50 mi. If you get a short circuit, a ground, there, you will find, by actual calculation, that the amount of power that will flow is small and is below the minimum limits of a 190,000-kv. circuit breaker.

That is a hard idea to get through at first, but you will realize it as you go into it. But that comes from the fact that we have a very high voltage and far distances. It is not true with our present installations. Conditions are not the same as they are in normal networks. These long-distance networks have a radically different character, and the great difficulty is to get enough synchronizing power between stations, and not too much.

The question of reliability is another very important one. It was in my mind, as it is in yours. But I feel pretty well satisfied, from what thinking I have done, that this network is far more reliable than the so-called trunk-line type of transmission. The principal reason is this. Supposing you have a receiving end here and a sending end here, with a transmission line between. If something happens to the center of that line, or any part of it, and you get a ground, you lose the voltage—there is practically no flow of power between one end and the other. You have lost your chance for holding synchronism.

On the other hand, where you have a scheme like this, where there are two or three different routes, you may get just as heavy a short circuit as you want on one route and there may be no interchange of synchronizing currents across that link; but the other link holds them in synchronism. And after a while, whenever you are ready and a good circuit comes back, they are still in synchronism.

That isn't the only thing to consider, but that is one of the essential points in keeping continuity of service in a network, and that, it seems to me, is pretty nearly enough to throw the balance in favor of the double link connection—seperate link sections between stations.

I maintain, also, that a single circuit, feeding a station from both directions, is safer than two circuits coming from a single direction, because no one accident can sever both connections. With the two circuits you feel pretty secure. But as you analyze it, you are safer where you have a single circuit which can be fed from both ends.

Of course, the question of relaying is a very important one, and I don't think there is time to go into it. But it is taken up in the paper to considerable extent. I have thought of it further than is in there, and while some new devices will be required, I believe that a relay system, at least as successful as the present one, can be devised. For example, where you have a series of stations on a long single circuit and you get a ground, it is a difficult thing to cut off the last end where the fault is and not cut off some other section. But we have an idea to work with there, which is a relatively new one, by which we can have time limits, on relays, and the relay will open quickest where the voltage on the circuit is the lowest.

On these long circuits, the voltage builds up very rapidly with distance. It is full voltage on one end and 50 or 75 mi. away there may be a ground on the other end. If the relay that has the lowest voltage on it opens first, that will clear the bad section. That isn't entirely worked out.

Aluminum was used in this conductor because of its larger bulk, so we could use a smaller size conductor equivalent resistance.

I did make the statement that I don't think it is safe to infer from present troubles in interconnections, because, with very few exceptions, there are no existing interconnections of the character of this.

Suppose you do build a trunk line to a center and your load leaves it—your trunk line is worthless. This system has the same conductor all over it, and it will permit, as I say, a change of 250,000 kw. in the supply of steam or water power, which is the balance that shifts with the seasons, from one side to the other, without any distrubance of voltage that the operating man will notice. The network is the thing which can stand an unexpected shifting in load much better than any other type that is proposed.

Mr. Skinner objects to too many taps on the transformer.

I don't think this as an actual installation would call for abnormal transformers. It is true, there would be a variation of about 10 per cent in the voltage that would require two or three taps. We would size it up as to what was going to be a good voltage for that station, and put it up two or three per cent, or down two or three per cent. The thing would go by steps.

You would have to have some taps. But you have two chances for taps—a chance on the 220-kv. transformers, the lower transformers, and also the chance to lower these drops that are taken. You could make a little more to Easley and a little less to Greenville, or a little less to Easley and a little more to Greenville. There are a great many devices you can use to avoid that particular trouble.

Mr. Oliver asked a question in regard to Muscle Shoals and cutting out the power there. That brings up again the point that I raised a while ago. Until you have studied this thing, you don't realize the different numerical relations that exist. Supposing the line did fall from Muscle Shoals to Huntsville. That means 238,000 kw. would have to go over the 88 mi. of line to Warrior over a single circuit. Warrior is a steam plant. Warrior has something like 100,000 kw. capacity. From that point the circuit splits. There are two circuits. The normal load is about 42,000 kw. in each one of those. It runs down to about 6000 kw. when you get to Anniston.

Now, that 88 mi. would take the 200,000 kw. without any trouble. The load, after that, divides in two—it adds 100,000 on those other circuits. But there is a steam station in Birmingham. At Jackson Shoals there is a steam station, and that power will merge in there and sluff away, and when you read your ammeter you will find there is a little higher load, but you won't find it in other parts of the system.

But for fear that would be considered too great a risk, I have dotted in a third circuit. You will notice the dotted line from Muscle Shoals to Huntsville, which runs down to Lindale and Atlanta. I felt, myself, that the thing was too precarious, so there is a whole spare circuit which is not used in the calculation on drop, which I have installed for the sake of giving more than two circuits to take care of Muscle Shoals. That is too much power to tie up to two circuits.

The same way at Cherokee Bluffs. While the dotted line from Newnan and Atlanta is not used in the calculation, it is put in for good measure, because you shouldn't tie up to much power to so few circuits.

CARRIER TELEPHONY ON POWER LINES[1]

(Slaughter and Wolfe)

Birmingham, Ala., April 8, 1924

H. L. Wills: When Mr. Slaughter announced that he was going to talk on one watt, I said to myself, "Good heavens, that's the same old thing all over again; that is what they always do—they keep going lower down in the scale of power, and we keep going the other way, and then they expect us to live together decently when we are both so far apart!"

So it brings to my mind this thought: What are the advantages to be gained by the use of approximately one watt in our telephonic inter-communication over the high lines? I would like to ask Mr. Slaughter if he thinks that is going to be ample to do our work?

Then there is the matter of coupling. I would like to ask if there is going to be any real gain in the use of condensers for coupling?

Then you know we have talked a lot about the telephone people getting off the ground with the power engineers, and the power engineers seem now to be getting back on the ground again. Now here comes along an organization, and they are getting off the ground again. What is the advantage of the full metallic circuit?

It seems to me that in starting out on a program of intercommunicating power lines or interconnecting power lines, our intercommunication system, if it is going to follow along our lines, should be ample; should be such that it can be used universally, and we should not spend time or effort in setting up a great number of systems and then later on in our stage of development find that some or most of it is all wrong.

Leonard F. Fuller: This paper describes work in which the interphase, or all-metallic, carrier-current circuit was employed, as shown in Fig. 1, in which 1 and 2 are coupling wires, or high-voltage coupling condensers, through which energy from transmitter T is fed to line conductors a and c and then to receiver R through coupling means 3 and 4.

The circuit comprises T, 1, 3, R, 4 and 2.

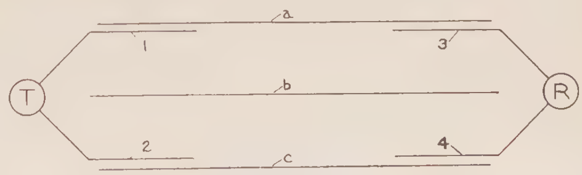


Fig. 1

If either conductors a or c open, test has shown that although the circuit is interrupted metallically, it remains closed electrically because of the capacitance between the unbroken conductor b and each portion of the interrupted conductor. The ground of the broken conductor at each end of the break seems to make little difference.

When both conductors a and c are broken and fall to earth, the condition is serious.

In Fig. 2, is shown the ground-return carrier-current circuit, in which 1 and 2 are coupling wires, or coupling condensers, arranged to feed into line conductors a, b and c operating in

1. A. I. E. E. Journal, Vol. XLIII, April, p. 377.

parallel. In this case, the earth completes the carrier-frequency circuit, and the interruption and grounding of any two of the three conductors has very little effect upon the energy arriving at the receiver from the transmitter T.

In the case of twin-circuit lines, five of the six line conductors may be interrupted and grounded without seriously interfering with the carrier communication.

This, in itself, is a feature distinctly in favor of the ground-return method, but on the other hand, the power required for communication between two points on a transmission system is very much less with the interphase method. Thus, if the power used with the interphase connection is increased to that necessary for successful operation with the ground return method, the transmitter of the interphase system will be able to operate through even more serious line interruptions than is possible with the ground-return circuit.

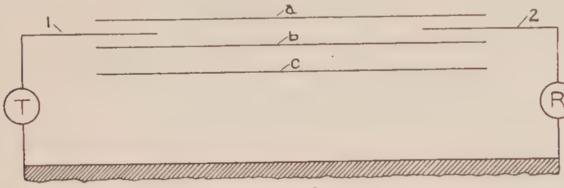


Fig. 2

The losses occurring in the case of the ground-return method, which require more power output from the transmitter, probably occur in the earth portion of the circuit.

It is possible that one reason why the interruption of all conductors is a more serious matter with the ground-return method than with the interphase system is because the group of line conductors which operate in parallel carrying the carrier-frequency current are usually considerably farther above the earth than the distance between phases, thus making the reactance of the circuit through which the carrier current is circulating much higher in the case of the ground-return method. Thus, a higher quadrature voltage is required to circulate a given current, and when all lines are down, the e. m. f. which must be induced at the receiving end of the break to produce a suitable received signal is much higher in the case of the high-reactance ground-return circuit.

For these reasons, the interphase method of operation is rapidly coming into favor for this type of communication.

L. P. Ferris: A joint field study of the transmission factors relevant to the problem of induction at carrier frequencies has recently been made by engineers of the General Electric Company and of the American Telephone & Telegraph Company, with the cooperation of the Testing Department of the Public Service Company of Northern Illinois. I hope that the results of this work may be made generally available in the near future. Some of the results relating particularly to the questions of line and transformer characteristics may be of interest now in connection with the discussion of the present paper.

Fig. 3 shows the ratio between the current received at the end of a 17-mile section of a 33,000-volt transmission line to the current sent into the line, for a "metallic circuit" of one pair of wires and also for a circuit made up of the three wires of a line with ground return. These curves are not smooth because the terminating resistance departs from the exact characteristic impedance of the circuit, as defined in the paper. At the time these tests were made the characteristic impedance of the circuit had not been accurately determined. The irregularities in the curve are probably due in a large measure to this departure from the correct characteristic impedance, under which conditions reflections from the far-end of the circuit are to be expected. Because of the much larger attenuation in the grounded circuit these reflection irregularities are less pronounced in the lower curve. Particularly at the high frequencies this curve becomes relatively smooth.

The curves in Fig. 1 bring out clearly the large difference in the attenuation in the "metallic" circuit and the circuit of the three-wires-to-ground. At 85,000 cycles the current received in the grounded circuit is 1/9 and the power therefore about 1/80 of that received in the "metallic" circuit for the same current and power transmitted. As noted in the paper under discussion, this difference is an important advantage in favor of the metallic circuit for this type of system.

The values of the current ratio above unity for the upper curve in Fig. 1 are due to the terminal irregularity and, of course, do not represent an increase in power although the received current may be larger than that transmitted.

In a foot note at the bottom of page 1 the authors give a formula by which the current ratio for a line of any length may be calculated from the ratios for a different length taken from the curve. This formula may be written in several other forms. For example, if R_2 is the ratio $\frac{I_r}{I_t}$ for length L_2 and R_1 is the corresponding ratio for L_1, then the equation may be written $R_2 = R_1^{\left(\frac{L_1}{L_2}\right)}$. This may also be written as $R_2 = \log^{-1}\left(\frac{L_2}{L_1}\log R_1\right)$. Either of these forms is useful in making simple calculations, and the first of the two may be particularly advantageous where use is made of the log-log slide rule.

Because of the losses in power transformers bridged across the circuit the question of the impedance presented by apparatus of this character at the carrier frequencies is of considerable importance. Messrs. Slaughter and Wolfe show the variation of the impedance between two terminals of a grounded Y-delta transformer bank, with the secondary side sort-circuited and with it open. It is of interest to examine the variation of

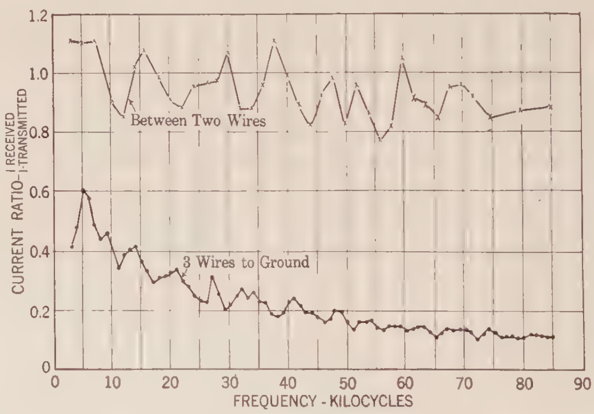


Fig. 3—Ratio of Received Current to Transmitted Current

17 Miles Section of 33-kv. Transmission Line

impedance of a single transformer with frequency, and also of the Y-connected bank when the impedance is measured from the three wires of the line to ground. Fig. 2 gives the impedance-frequency characteristic of an 8333-kv-a. transformer rated at 21,000 to 12,000 volts. This is a single-phase unit operated in a 25,000-kv-a. bank on a 33-kv. system. The curve shows the impedance-frequency variation for five resistances across the secondary terminals. These are 0, 17.3 ohms, (which is the resistance required to give full load current of unity power factor) 1000 ohms, 6800 ohms and infinite resistance The effects of resonance of the transformer windings at certain frequencies are shown very clearly The curves for low secondary impedance show low values of primary impedance in the lower frequency range with humps appearing at about 43,000 and 70,000

cycles. The high secondary impedance curves show large values in the lower frequency range, trailing off to low values at the higher frequencies Where a metallic circuit is used and transformers connected in star, the bridged impedance presented to that circuit will be twice the impedance of one transformer, as may be seen from Fig 2 of the paper where the impedance is measured between two terminals with two transformer windings included between them, In the range above 30,000 cycles the

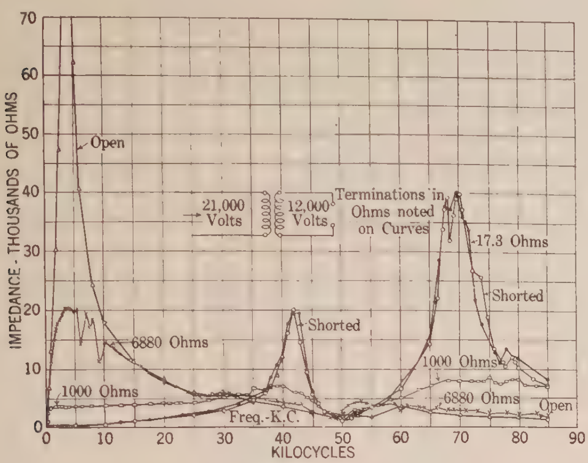


Fig. 2—Transformer Impedance
8333-kv-a. Transformer, 21,000-36,300 Y/12,000 Volts.

lowest bridged impedance obtained for any value of secondary impedance shown in (Fig 2) is approximately 1500 ohms, or the equivalent of 3000 ohms for two transformers in series. For the lower secondary impedances which are much more likely to obtain under practical conditions the primary impedances are generally considerably higher.

Fig. 3 gives the impedance of a bank of three transformers of the same type as used for the measurements on the single unit just discussed. For this test the bank was connected Y-delta.

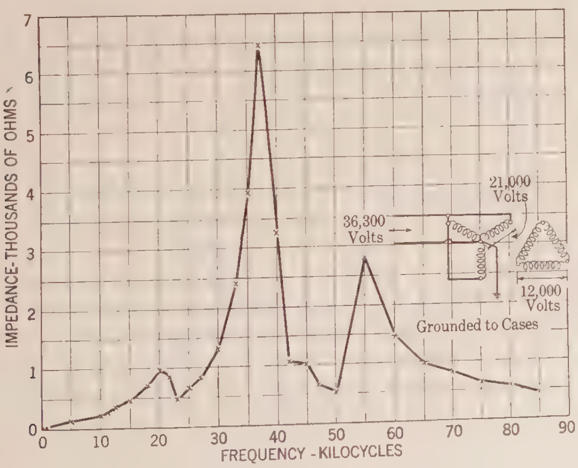


Fig. 3—Transformer Bank Impedance
3-8333-kv-a. Transformers, 36,300 Y/12,000 Volts.

The delta was closed and the impedance was measured between the three line terminals in parallel and the neutral. It will be observed that this transformer bank introduces a bridged impedance between the three wires and ground varying between 500 and 6500 ohms in the range of above 30,000 cycles. In this range the impedance at any frequency is less than twice the impedance of a single transformer at that frequency as shown by (Fig. 2). From this and other cases giving similar results, it is believed that the use of a two-wire metallic circuit is to be preferred to that of the circuit between the three wires and ground from the standpoint of bridged losses due to Y-grounded transformer banks.

Fig. 4 shows the impedance between the three line terminals of a 33,000-volt, 225-kv-a. transformer bank and ground with the secondary connected in delta. The impedances for this transformer bank are all higher in the range above 30,000 cycles than those of the 25,000-kv-a. bank shown in Fig. 3, due to the lower power rating of these transformers, and similarly higher impedances were found for the single units comprising this bank. The three curves on this slide show the primary impedances under the following conditions:

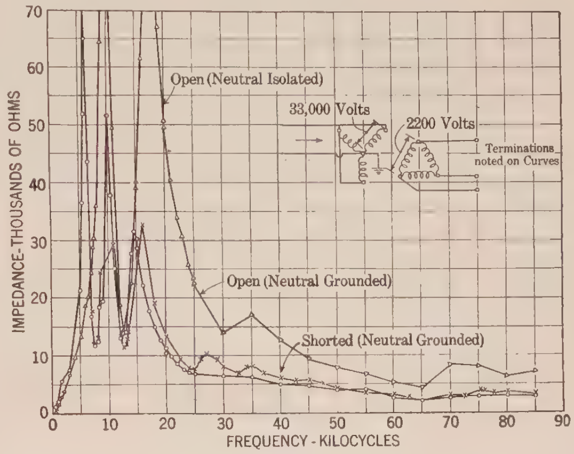


Fig. 4—Transformer Bank Impedance
3-75-kv-a. Transformers, 33,000-11,000 2420-2200-1980 Volts.

1. Primary neutral isolated, leads from secondary delta open.
2. Primary neutral grounded, leads from secondary delta open.
3. Primary neutral grounded, leads from secondary delta short circuited.

In the major part of the carrier range these curves show that grounding the neutral to the case reduces the impedance to about half its value with neutral isolated.

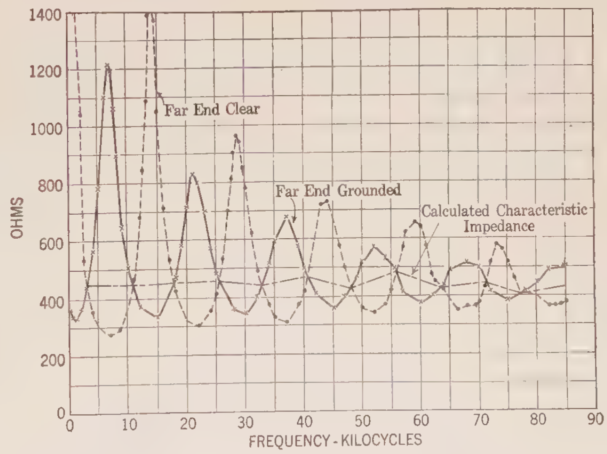


Fig. 5—Transmission Line Impedance
3 Wires to Ground, 5.7 Miles Section of 33-kv. Transmission Line.

Fig. 5 is shown in order to exhibit the manner in which the impedance of the three wires of a line in multiple to ground varies with frequency. The dotted curve shows the impedance to ground with the far-end of the circuit clear of ground, whereas, the solid curve shows the impedance with the far-end grounded. The peaks of these curves are of course due to reflections from

the open or short circuited distant end of the line and the frequency intervals between peaks are determined by the velocity of phase propagation and the length of the section measured. Because of the increase in attenuation as the frequency is increased the magnitude of these peaks diminishes towards the higher frequencies. It may also be noted that at the upper end of the frequency range these curves are approaching a common value, which is the characteristic impedance of the circuit or the impedance that the circuit would present if it were infinitely long. As noted at the bottom of page 1 in the paper the characteristic impedance of the line (or the impedance with which it must be terminated to avoid reflection) is given by the formula

$$Z_c = \sqrt{Z_o \times Z_s}$$

where Z_c is the characteristic impedance, Z_o is the impedance with the far-end of the circuit open and Z_s is the impedance with the far-end of the circuit short-circuited. The characteristic impedance for this line has been calculated from the open and short-circuited impedances and plotted on the curve for reference. It varies somewhat with frequency and lies in the range between 400 and 470 ohms. This slight variation is explainable by variations in the gage and arrangement of the conductors along the line.

It should be pointed out that not only the impedances but also the attenuation factors for high tension lines vary over a considerable range for different types of circuits and also vary considerably for circuits of the same type, depending upon circuit conditions. Variations are produced by the presence of other wires (including ground wires) on the same lead which absorb energy. It is very difficult to say just how these variations are produced or to give any reliable method of calculating their effects. For approximate calculations, however, it is permissible to assume that the attenuation factors for one line may be applied to another line of similar construction when the appropriate circuit lengths are taken into account.

G. Y. Allen: The matter of attenuation was rather interesting to me. Fig. 1 of Col. Slaughter's paper shows the attenuation for a typical power line with no connected apparatus and with an impedance connected at the receiving and transmitting ends of the line corresponding to its surge impedance. Under those conditions, of course, there will be no reflections along the system and the attenuation can be easily calculated.

Fortunately or unfortunately our pioneer experience was obtained on the lines of the Duquesne Power Company of Pittsburgh. In contradistinction to a straight line, with no connected apparatus, the Duquesne System consists of distribution rings of various voltages to which are connected a vast amount of apparatus. In attempting to apply carrier-current telephony to this system, it was very difficult to predict the results from day to day. The apparent reason is that with so much connected equipment and with such a complex network the constants of the line changed rapidly, even from hour to hour, and the performance of such a network cannot easily be calculated. We found, for instance, that it was necessary to change the wavelength that was used in order to insure communication even during as short periods as one hour.

I merely bring out this point to emphasize the fact that the calculation of the performance of a network is not always as simple as Fig. 1 in Col. Slaughter's paper would indicate. As a matter of fact, our experience indicates that the majority of networks are much more complex than the one Col. Slaughter has considered. It is on account of this indeterminate factor that the Westinghouse Company have constantly advocated the use of surplus power to reduce the probability of interruption of communication to a minimum. It is a well appreciated fact that communication is most essential in time of trouble. If carrier-current telephony is to serve the power industry as it must be served, it must operate during abnormal line conditions.

There is one other thing in connection with coupling that I desire to touch on. Col. Slaughter states that the efficiency of condenser coupling is much greater than antenna coupling. This is probably true. Our results have indicated that instead of getting approximately 80 per cent of the energy in the oscillating circuit on the system, which is probably the efficiency of condenser coupling, antenna coupling may give considerably less. We appreciate this relation and our only reason for continuing to use antennae is on account of the reduction of hazard, and also due to the fact that on high-voltage lines we have not yet seen a condenser that we feel will stand up. We have some thoughts worked out on paper for the improvement of antenna coupling and our present policy is to continue to use antenna coupling for potentials about 30,000 volts.

E. R. Craft: It seems to me that what the power companies are going to need is a means of inter-communication and intra-communication which will render the most reliable service at the least possible cost. Whether or not it will be antenna-coupled or condenser-coupled, it is going to be worked out eventually and adopted.

It is not a question of using one watt or 500 watts of energy, but of obtaining the system fundamentally most efficient for the purpose. Then there can be used whatever amount of power is required.

In considering the type of system that is going to be employed by any individual operating company, thought must be given to how this is going to work into the other systems with which it must connect sooner or later. Take the Southeastern district, for instance. The system is not the system of the Alabama Power Company nor that of the Georgia Railway and Power Company. It is the power network of the entire district.

W. V. Wolfe: Considering Mr. Wills' discussion, his first question was: "What are the advantages of low power over those of higher power?" Mr. Craft has already answered that in a certain measure and there are only one or two points which I want to make in connection with that. The first is this: A telephone system must be duplex in its operation, in order to be a telephone system. The problem of making a telephone system duplex increases materially as the power which you use in transmitting increases. As we have pointed out in our paper, you have to operate your transmitting circuit in parallel with your receiving circuit. The ratio of power required to operate the receiving circuit to that required for the transmitting circuit may be of the order of 10,000 to 1, and obviously as you increase that transmitted power, the difficulties of keeping those two things separated increase very materially.

Mr. Wills' second question was with regard to the coupling wire versus the condenser. In the first place, the coupling wire does not give as safe a method of coupling to the power line as the condenser does, first, because the coupling wire extends 1000 or 1500 ft. in parallel with the power conductor itself. It is true that it is put up in the same manner, of the same size conductor, and in every way as nearly as possible the same construction as the power line itself, and the possibilities of its failure are no greater than those of the failure of the power line, but power lines do fail, and this 110,000 volts or higher may come in contact with the antenna wire over this range of 1000 or 1500 ft. By using the condenser, we put that possibility of failure in one spot: we don't extend it over 1500 ft.; and in addition to that, the condenser, because of the different methods with which it is used in coupling to the power line, gives a scheme which is very much safer than the coupling wire.

In connection with that I want to say here that in our demonstration or proposed experimental work at Magella, we had the failure of a condenser, probably due to the condenser being damaged in shipment, but at any rate, regardless of the reason for the failure of the condenser, this condenser failed while the man was talking on the circuit. This man who was talking on the circuit when the condenser failed is in the room this evening; he was listening on the circuit at the time of failure. The only thing that happened was that he got a little click in the

receiver, and he was called out by the operator of the station who had heard the fuse go out. I don't think we can assume the same degree of safety with the antenna wire strung parallel to the power line wire for a distance of 1000 or 1500 ft.

Mr. Wills also asked the advantages of the full metallic circuit over the ground-return circuit. Dr. Fuller has pointed out many of those advantages; our friend from the Westinghouse Company has also pointed out some of those advantages. There is one thing which I believe neither of those gentlemen has pointed out, and that is this: That the antenna scheme of coupling on a full metallic or a ground-return basis leads to a certain loss due to radiation of power from this coupling device. With the ground-return circuit, the radiation, as measured in experimental work which we have done, is of the order of four times that encountered in the full metallic circuit. That in itself is not important, except for the fact that the business of radio communication, of broadcasting, is developing at a tremendous rate in this country, and the government is very anxious to keep radio where radio belongs. It is only a question of time till a carrier system or any other system which radiates into the ether will have to meet certain government requirements. They may not be the same requirements that are asked now for a radio station, but they will certainly have to be regulated by the government.

One question which Dr. Fuller brought up was the question of one wire failing on a full metallic circuit. The only thing I can say there, and the only thing I believe we can say for any carrier circuit or any communication or power circuit is this: That as long as the circuit is in tact, you will be able to talk through it. What constitutes a carrier circuit may be something entirely different from what constitutes a power circuit. A failure of one wire may, under certain conditions, constitute a failure of a carrier circuit; under other conditions it may not constitute a failure of a carrier circuit. I may say, under certain conditions, we have not only been able to talk through it with one-wire conditions, but we have talked with three wires opened and grounded. It may result in a failure of the carrier circuit, but does not always result in such a failure.

Another thing in connection with the ground return and the full metallic circuit is this, as pointed out by Dr. Fuller and Mr. Allen: The fact that in the ground-return circuit; if you take the transformer off the line, you are going to change the character of the ground-return circuit from a transmission standpoint, and that change may be of an order of magnitude which may result in a failure of the carrier system to operate. We don't find that condition to be true in the full metallic circuit. We have at all times operated our experimental metallic circuits without information as to whether there was a transformer on here or on there; it made no difference.

There is just one other point I want to mention, and that is the cost of condensers as compared with the cost of antenna schemes. I think the point there has been overlooked. The important thing in a communication system, which may mean the successful operation or the failure of the operation of a power system, is not the cost; the cost of these condensers being small as compared with the cost of the power apparatus used in a big power network. If they are going to mean the difference between a successful carrier system and an unsuccessful carrier system, then I do not believe that any power company can afford to let the economics of that thing hold them up.

A NEW SELF-EXCITED SYNCHRONOUS INDUCTION MOTOR[1]

(FYNN)

BIRMINGHAM, ALA., APRIL 9, 1924

S. R. Bergman: I think this new motor is a courageous attempt to deal with a difficult and complex problem, namely, the problem of power-factor correction.

This motor is of the synchronous type and therefore has a constant speed over the running range. This feature, however, is of no advantage since experience has shown that the small amount of slip in the standard induction motor gives an excellent speed characteristic.

In judging a new type of motor the main question is, of course, one of economy. The motor which shows the lowest yearly operating cost to the user is the best motor. In dealing with the yearly operating cost of any electrical apparatus there are certain items which require consideration: 1st: Cost of power; 2nd: Interest and depreciation; 3rd: Maintenance; and 4th: Losses caused by interruption of service due to needed repairs.

When considering the cost of power of a motor we meet at once with difficulty due to the fact that the rates are not uniform for the whole country. Not only do different systems charge different amounts per kilowatt, but the charge due to low power factor is one that is causing a great deal of uncertainty, since no definite policy has yet been adopted. At present a number of systems have established penalizing clauses which, however, are often not enforced. Until some definite rules are established it becomes rather difficult to determine the advantage of this new motor, which possesses inherent power-factor compensation.

While this motor can be adjusted for unity power factor or even for a leading current, it strikes me that the construction of the motor is such that it has inherently a lower efficiency than the standard induction motor. I do not hesitate to state that in my opinion, if this motor is adjusted for unity power factor the yearly cost of operation will be higher than that of a standard induction motor. This unfavorable condition is mainly due to the additional losses caused by brush losses, excitation losses, etc.

When this motor is adjusted for leading power factor it probably has a better chance of utility since mixed with ordinary induction motors it will correct the power factor. On the other hand, there are other ways of correcting the power factor which are being successfully utilized. I mean the use of standard synchronous motors, rotary condensers and static condensers. Synchronous motors of the standard type and rotary condensers are quite advantageous in large units and the static condensers in smaller units. By a proper application of such apparatus, excellent results have been obtained. The natural evolution taking place in the electrical industry will of course, determine which of these methods is the most economical to employ to correct the power factor.

The third item referred to above was the cost of maintenance. This new machine possesses a commutator as well as slip rings and therefore, requires two sets of brushes. I also notice that it requires a starting resistance. As I understand it from the description, the armature carries two windings and the field also contains two windings. It seems to me the conclusion is obvious that this motor has a cost of maintenance far in excess of that of the standard induction motor.

Then we have the question of interruption of service caused by possible repairs. It seems that this new motor with its complicated structure would not be as reliable as the simple induction motor and therefore, would cause more lost time due to repairs which is a very serious matter to the user.

The motor industry as we know, is developing very rapidly as new water-power projects and interconnected systems are being developed in the country. The motor business and the electrical business as a whole doubles every fourth or fifth year. If the electrical industry is going to continue to be successful it is absolutely necessary that it develop along sound lines, that is, along lines which are simple so as to secure continuity of service. When judging any new piece of apparatus this point of view is of fundamental importance and with respect to this new motor its complicated structure is therefore a matter to be given serious consideration.

W. F. Dawson: I am not going to speak much about the

1. A. I. E. E. JOURNAL, Vol. XLIII, August, p. 744.

motor; I think Mr. Fynn can amply defend it, but I will say a word about the effect of power-factor correction on the main generating outfit. I speak with particular feeling for the turbine alternator.

I will use the simple diagram representing the excitation of turbine alternators. Our conventional design will call for saturation 1.00 and impedance approximately equal, 1.00; 80 per cent power factor, which means 60 per cent reactive component. That gives a full-load excitation of 1.79. If the generator were operating without any reactive component and the same kw. the excitation would be 1.28; or if at unity power factor and the full kv-a. rating of the unit, the excitation would be 1.41.

The power companies pay for all that reactive component. It is the field excitation of turbine alternators, in most cases,

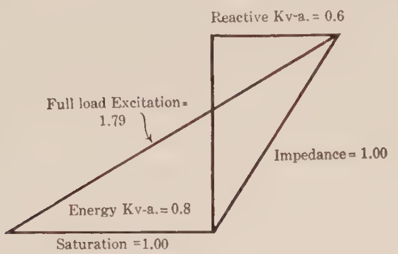


Fig. 1—Excitation Diagram. 1.00 Kv. 0.8 P. F.—0.8 Kw.

that determines their maximum capacity. If this particular example were operated at unity power factor, it would have 25 per cent more kilowatt capacity and would save the difference between 1.79 and 1.41 in field excitation. In other words, if the output were limited by field capacity, the unit would have the margin represented by that difference.

I don't say that the remedy is better than the disease; we will let Mr. Fynn say that. What is wanted, however, is better power factor every day, in every way, all the time. Furthermore, look at the investment in your lines. Even though the turbine alternators do manufacture a 60 per cent reactive component in addition to the 80 per cent energy component, the lines do not have to carry the arithmetical sum but they do have to carry the vectorial addition.

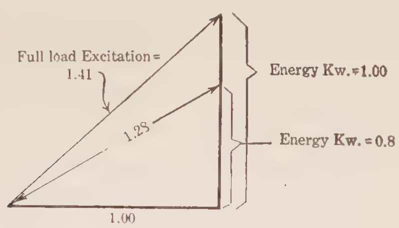


Fig. 2—Excitation Diagram. 0.8 Kw. and 1.00 Kw. 1.00. P.F.

Condensers, static or synchronous, might be placed in the power houses with the generators and thus help out the generator fields, but that would not relieve the lines of the extra load due to the reactive component. The proper place for condensers is at the point of final distribution where the power is used.

F. J. Rudd: I am particularly interested in so-called small motors, say 50 h. p. and below. To-day where individual drive is becoming more and more common, the standard mechanical construction is not always applicable. Specialization is required in many cases and it appears from the construction of this particular motor that many difficulties would be encountered when trying to fit it to various applications.

From the standpoint of certain atmospheric conditions, in many cases standard open squirrel-cage motors are satisfactory; whereas, a motor with commutator and collector rings would have to be totally enclosed. This in itself would materially increase the frame size and hence the cost for a given rating.

Another point is that where the primary voltage is higher than the normal of 550, say, for example, 2200, the problem of insulating the revolving primary winding would be much more difficult and expensive than would be required for a stationary winding, such as is employed on the usual squirrel-cage type of machine.

V. A. Fynn: The discussion brought out a point on which I have perhaps not laid sufficient stress in my paper. I was particularly interested in showing you just what theory is involved in the solution of the various problems connected with this type of motor. I think I did mention in the paper and also in my presentation that this machine could readily be inverted. This is, of course, quite simple, and when you do so, you get away from all insulating difficulties because the primary is then located on the stator. With the primary on the stator, revolving brushes must be used so long as the machine is self-excited. This revolving-brush problem has been attacked and it appears that it is capable of quite a simple solution.

But even when that is done, all of Mr. Bergman's objections are not met. I am not presenting this as a universal solution for the difficulties about which we all know, and which were so ably emphasized by Mr. Dawson. This is only one step towards a complete solution. This machine cannot compare with the squirrel-cage motor. The squirrel cage is supreme in its field, but it has a poor power factor, and the only remedy that I know of, in so far as the squirrel-cage motor is concerned, is the use of static condensers. Static condensers, theoretically, are simple enough, but they are still very expensive and have their drawbacks. If you connect static transformers to your motors, you soon run into difficulties such as have been met in Europe. Condensers are responsive to all frequencies and for that reason often exaggerate high-frequency disturbances.

The principles which I have outlined in my paper are also applicable to large separately excited machines; not only to machines of 50, 60 or 100 horse power, but to any size of machine. Just how this is done I shall have the pleasure of telling you in another paper, but in principle the solution is much the same.

While I do not claim this new motor to be a perfect machine, yet it is better than any other now available and when built with the primary on the stator and with the revolving secondary carrying the unidirectional excitation, it provides a reasonable solution in many cases.

THE 65,000-KV-A. GENERATOR OF THE NIAGARA FALLS POWER COMPANY[1]

(Foster and Glass)

Birmingham, Ala., April 9, 1924

R. B. Williamson (by letter): This paper is of special interest to me because I happened to be responsible for the design of one of the 32,500-kv-a. units installed in this station in 1919, and also have had in charge the design of a 65,000-kv-a. unit which will be put in the same station alongside the unit described. At the time the 32,500-kv-a. units were started, they were the largest of their kind but they had been in operation but a short time before plans were made by The Niagara Falls Power Company to install three additional units of 65,000-kv-a. output. The three 32,500-kv-a. units have now been in operation for four years or more and have given excellent service. Further, these units showed a very high efficiency, 97.5 to 98 per cent, and the larger unit was not adopted with the expectation of securing any material gain in efficiency. Neither does the large generator cost appreciably less per kv-a. output, since the speed is lower and the weight per kv-a. somewhat higher. It may be repeated here, that the 32,500-kv-a. units operate at 150 r. p. m. as against 107 r. p. m. in the case of the 65,000-kv-a. machine.

1. A. I. E. E. Journal, XLIII, April, p. 365.

Referring to Fig. 4, it will be noted that the floor space occupied by the large generator is approximately 725 sq. ft. as compared with 365 sq. ft. for the smaller unit. Thus the floor space is almost double so that space per kv-a. is about the same in either case, so far as the generators alone are concerned. However, when all other features, such as necessary space between units, space for auxiliaries, penstocks, etc., are taken into account, it is evident that three of these large units can be put into a shorter power house than six units of 32,500 kv-a. each, and as the space available for the power house was strictly limited in this case, the larger units were chosen. In other words, it was necessary to place the largest possible generating capacity in a limited space and the 65,000 kv-a. generators in this respect were superior.

So far as the construction of the stator is concerned, it is essentially the same as that of the smaller units, though, of course, the machine is larger in diameter and higher. The chief structural differences are in the rotor which, on account of its large diameter, had to be sectionalized to a greater extent. In the unit described, the rotor spider is in ten sections, each consisting of a half wheel with the rim cast integral with the arms and half hub. The five wheels assembled on the shaft form the complete spider to which the poles are bolted. As stated in the paper, the design to be used for such a large spider is one that involves a number of considerations. Not the least of these is the ability of the steel founder to produce satisfactory castings. Such a design has to be worked out in consultation with those who make the castings and very often the design has to be modified to conform to their requirements. Thus, designs that are quite different, may result and yet each be entirely satisfactory. In the design with which the writer has had to do, the rotor spider is in two wheels, each of which is made of seven sectors having two arms per section. The two hubs are separate castings and the arms are bolted to heavy flanges on the hub by means of reamed bolts in the same manner as has been used for many years for large segmental engine fly wheels. The sectors are joined at the rim by heavy mild-steel tongues and dowels, and the poles are bolted to the rim. Test bars from all the rotor castings were taken from coupons and also from samples drilled from the body of the rim by means of hollow drills.

As stated in the paper, the problem of bending the field copper on edge for a field coil of this size is quite a difficult one but it has been successfully accomplished and the coils present a good even appearance. This is only one of the many problems that have to be solved in the construction and erection of such a large unit and the authors are to be congratulated on the results obtained. The writer had the pleasure of witnessing the starting of the first of these units and notwithstanding the enormous size of the machine, its operation is smooth and quiet. The third unit is now being installed and I hope at a later date to present a detailed description of it to the Institute. In external appearance and dimensions, it differs very little from the one described in the paper; in fact the engineers concerned, co-operated in every way possible to make the units present a uniform appearance and the differences are mainly in details of design which I hope to describe later.

W. I. Slichter: This paper is an important addition to the very few we have had on the subject of the design of large generators. In the PROCEEDINGS of the Institute there was in 1914 a description of a 7500 kv-a. machine; in 1923 a description of a 32,500 kv-a. machine; in 1922, of a 45,000 kv-a. machine and this year, 1924, of a 65,000 kv-a. machine. This enumeration shows the rapid increase in capacity of water-wheel generators, as each machine described was the largest of its time. It is interesting to note that in this latest machine efficiency was given more consideration than heating, showing the effort for very high efficiency. In most large machines, if the heating is satisfactory the efficiency will also probably be satisfactory. It is well known to designers that in small machines it is difficult to get a good efficiency and if this is obtained no difficulty is experienced with heating. In large machines, particularly turbo generators, the heating is the more difficult problem and if this is satisfactory the efficiency is also satisfactory. This machine therefore marks a still further step in the development of our designs, in which the conditions have reversed themselves as the capacity increases above a certain very large figure.

The use of a fractional number of slots per pole ($12^6/_7$ slots per pole) to eliminate higher harmonics is a matter of interest as this practise, which has only been introduced in the last few years, is quite a conundrum to the engineer without experience in design, and yet it is quite a natural and desirable advance in the art of making windings to give a good electro-motive force wave-shape.

In order to compare the weight economy of this machine with others it is necessary to take into account many factors and this is best done, for purposes of comparison, by a formula, which has been applied to many lines of machines. This formula is

$$W = K \sqrt{\frac{P}{R.\ P.\ M.}}$$

in which W is the weight of the machine in pounds; P, the kv-a. rating of the machine; and $R.\ P.\ M.$, the revolutions per minute. K is a characteristic constant of a given line of machines. Thus in well known lines of sixty-cycle turbo-generators, K would run from 40,000 to 50,000 and in a line of similar machines for twenty-five cycles, K would run from 50,000 to 60,000. In the machine under discussion, K has a value of 58,000, so that this is an example of a water-wheel-driven machine of 187 rev. per min. and 8200 ft. per min. peripheral velocity which has a weight factor constant very close to that of turbo-generators which are generally understood to have a very good weight economy.

L. W. W. Morrow: One of the interesting features of this machine is the fact it has been installed at Niagara Falls; the development of hydro-electric machinery at this location has influenced the art in all parts of the world. The design of machines for this installation is unusual in that designers are given freedom to design the best possible machines and are not limited by cost values to the degree found in other locations where the units are small and the firm power is less in amount. Niagara Falls has a large and constant amount of available power which is sold largely near the development site. A fraction of a per cent gain in efficiency or in reliability on such large units and under the conditions found at this location can be capitalized for a very large sum and efficient production outweighs first cost many times.

L. P. Ferris: Mr. Foster mentioned the fact that the large 65,000-kv-a. machine described in the paper by himself and Mr. Glass has a fractional number of coils per pole, for the purpose of eliminating the higher harmonics. This is a very welcome step, from the point of view of the telephone engineer who has to deal with the effects of these higher harmonics on parallel circuits.

W. J. Foster: Mr. Dawson has asked the question about how the various losses have been determined. They have not been determined yet on the 65,000-kv-a. machine, by actual test, but they will probably be determined in about two months as soon as the second generator has been in service for a short time. The method that will be employed is the retardation method, the same as used in connection with the testing of the three 32,500-kv-a. generators. That gave most excellent and consistent results, as applied at Niagara Falls under the direction of Mr. Johnson. The retardation tests will be made on open circuit without any excitation, in order to determine the combined friction and windage losses; then under different degrees of excitation, to a considerable over-excitation. With all those curves, there isn't a shadow of a doubt as to the proper determination of the friction and windage, and of the core losses on open circuit.

Then the load losses will be determined by making similar retardation tests with the armature short-circuited, with an excitation that will give the full-load current carried during the retardation, at the 25-cycle point.

Those tests, as applied to the first generators, agreed very closely with the calculated values, showing lower figures in the case of the core losses, and practically the same as used in the calculation of efficiency for the remaining losses. But we already know from the 65,000-kv-a. machine that is operating, what its copper losses are, since we have the resistance of the armature and have determined the excitation required, which is a little lower than allowed in the calculations. So we have not much doubt that the efficiency mentioned here will be attained.

There are one or two features of that generator, that have not been brought out in the paper, and I didn't bring them out in the introductory remarks. One of these is the ventilation at the heads of the armature. The customer is very much concerned that every precaution against damage or of possible burning out of an armature coil should be taken so as to minimize the consequences of such a burn-out, and for the first time in connection with any generators that I have anything to do with, a very determined effort has been made to stop completely the swirl of air in the projecting windings of the stator. That swirl of air, especially in high-speed machines like turbine generators, once it catches fire, results as a rule in the destruction of the entire winding. In the case of slower speed machines, water-wheel machines, the damage often spreads around a considerable distance. But this particular generator, after a great deal of thought and numerous designs, has been equipped with a series of vanes at top and bottom, these vanes being made of an insulating material and also of fireproof, fire-resisting material.

HARMONICS DUE TO SLOT OPENINGS[1]

(Weber and Lee)

Birmingham, Ala., April 9, 1924

L. P. Ferris: The paper by Messrs. Weber and Lee shows that, from the point of view of the power company, or power user, there is some advantage in the elimination of the higher harmonics which, as you all know, have a detrimental effect upon neighboring communication circuits under some conditions of association.

Some years ago, in connection with the work of the Institute Standards Committee, an effort was made to determine what effect these harmonics might have from the standpoint of the power user. This did not arouse much interest, and I have no doubt that the problem is not of large magnitude from the power man's standpoint. But it is interesting to find that, under some conditions, these harmonics—even the slot harmonics—do produce effects which it is worth while, from this standpoint, to get rid of. This gives an additional incentive to the designers for a high degree of purity of wave form.

This paper comes at a time when there is being instituted a joint research, looking toward the determination of ways and means whereby the effect of harmonics may be determined and an examination made as to the practicability of improving the wave shape of machines. The manufacturers and the power companies are joining with the telephone engineers in this work, and I hope that the methods of analysis given in this paper may lend themselves to this study, in the direction of making it easier to find ways and means of improving the wave shape. I have no doubt that the designers are alive to this question.

THE APPLICATION OF AUTOMATIC CONTROL TO MINE SUB-STATIONS[2]

(von Sothen)

Birmingham, Ala., April 10, 1924

C. A. Butcher: The equipment of the earliest installations of automatic substations in mines was considerably more complex than was required for this service. Today the coal-mining substation, automatically operated, is a great deal simpler.

The equipment is now so nearly standardized, that we order it practically on style number. There are very few of the orders which actually go through the Engineering Department for information. The applications on which special features are required, of course, come to us, and those involve more the determination of the proper size of unit and whether, for example, a motor generator or converter should be used.

It has been determined quite definitely that machines in automatic operation may be applied more nearly on the basis of their continuous rating, rather than on the basis of commutation. Of course, the loads in a coal mine consist of a series of very sharp peaks. Consequently, the machine is applied, you might say, on its commutating capacity and very seldom reaches a temperature which is in accord with its continuous rating.

The very nature of the overhead and distribution in the coal mine makes it not permissible in a great many cases to attempt to hang onto a short circuit such as, for example, we often do in street railway service. That is for the reason that fires may be started and a great deal of damage result. We therefore have practically standardized on the automatic reclosing type of d-c. feeder breaker.

Also the station once started runs practically continuously throughout the day or during any one working shift, and it is therefore not necessary to provide automatic operation of the primary circuit breaker on the line side of the transformers. The real economics of the oil circuit breaker in most applications, is the fact that it saves the transformer losses during periods of idle or light-load operation. Since the saving in transformer losses is very small, it will not ordinarily pay the fixed charges on investment in high-tension switching equipment, so the transformers are often fused directly to the line. Where an oil circuit breaker is used, it is usually operated in the same way as when applied to a manually operated substation.

One coal-mining company in the St. Louis district has fourteen automatic substations. The 2300-volt cable is carried down a bore-hole from the surface. There is an auxiliary oil circuit breaker in the 2200-volt lead which affords protection to the motor-generator set and also to the cable at both ends. This switch is normally closed and opens only in the event of some serious disturbance in the mine or should the operator go into the mine to make an inspection of the equipment, he may open this circuit breaker in order to eliminate the hazard of contact with the high voltage circuit.

The application of automatic substations to mines has perhaps completely changed the idea of power distribution in mines and has eliminated the necessity of some very heavy cable runs which were ordinarily required where the substations, of necessity, were located so that an operator might give attention not alone to substation apparatus but to other equipment as well.

Since the advent of the automatic substation for mines, the same equipment has found very many applications in other classes of industrial service; for example, in foundries and in some steel mills where only a small quantity of power is required and where it would be very expensive to have an operator attend to such a small station, and again where it would be very expensive to reach that load location from an existing substation. Because of the regulation, very heavy runs of copper would be required. The automatic substation eliminates this and really makes a very economical installation by saving considerable power.

C. H. Matthews: As Mr. von Sothen states it is difficult to obtain capable mine substation operators except at prohibitive rates. A young man will not accept employment of this kind except at a high wage and older mine employees not being familiar with the operation of electrical apparatus do not maintain the equipment in first-class condition with the result that serious breakdowns frequently occur.

1. A. I. E. E. Journal, Vol. XLIII, December, p.

2. A. I. E. E. Journal, XLIII, August, p. 729.

The necessity of maintaining good operating voltage to locomotive and cutting machine motors is of vital importance.

At a certain mine in Ohio the mine foreman was continually complaining that he could not secure sufficient power from his two 100-kw. motor generators. The local management purchased a 200-kw. set and I was requested to make the installation. One of the small machines was taken out during a Saturday and Sunday and the larger unit installed in it place. On the following Monday all of the machine operators went out on a strike as they did not have sufficient power. A hurried investigation was made and it was found that the voltage dropped to 50 volts at the working places when the machines and locomotives were started. The circuit breakers in the sub-station did not open due to the larger capacity feeding into the high-resistance tracks and feeders. It was found that the tracks were not properly bonded and all feeder-line joints were made by twisting the wires together.

By locating one of the sets near the working places and installing either full or semi-automatic control the cost of the 200-kw. set could have been saved as the additional feeder copper installed would have paid for semi-automatic equipment.

The power loss in tracks and trolley lines, the cost of heavy feeder copper, the maintenance on locomotives and cutting machines, lost production due to low voltage and cost of manual operation can be more than compensated for in the majority of the installations at coal mines by the use of automatic sub-station equipment properly located and I believe it will only be a few years until the manually operated mine sub-station will be a thing of the past.

NOTES ON MINE HOISTING[1]

(Stone and Grant)

Birmingham, Ala., April 10, 1924

Carl Lee: The close agreement between the calculated cycle and the actual cycle of operation is very interesting and illustrates the high accuracy to which the design of electric hoists has been developed.

The smoothing out of the various curves has been noted on several hoists which have been in operation several yeras. The changes of the rope from the cone to the cylindrical part of the drum do not produce sharp changes in the load but rather gradual changes.

The efficiency of an electric hoist apparently remains very constant over a period of years as borne out by the attached figures which show the power consumption on two Ilgner Ward-Leonard hoists which have been in operation for over nine years.

This constant efficiency will be interesting to operators because with a steam hoist there is no doubt a falling off of the efficiency of the boiler plant, steam line, and steam engine after a few years use under average conditions.

W. I. Slichter: There are four important points brought out in these papers which seem to me warrant particular emphasis, as they indicate a general trend in the electrical engineering of the day.

The first point is the scientific calculation of the drum of the hoist by which the rate of acceleration is so controlled that the maximum demand on the hoist motor is limited to a reasonable peak and the load made nearly constant. This makes for economy in the size of the motor and the first cost.

The second is the use of the fly-wheel in the motor-generator set which still further reduces the maximum peak demanded of the transmission line, so that this peak is about ten per cent greater than the average. This makes for economy in the size of the transmission line and of the generator, again saving capital.

The third is the introduction of automatic control in the stations, making possible a notable reduction in the number of men required, thereby making for economy in the item of operating expense.

Finally, there is an effort to show consideration for the men, eliminating the danger of accident and enabling the men to live under more humane conditions, which illustrates the social and humane work of the engineer of the present day.

G. H. Finks: We have in Alabama quite a few electrified hoists, but no shaft hoists. The general data presented in the excellent paper of Mr. Stone and Mr. Grant does not apply in general to Alabama conditions, but the figures show that the calculated values for hoisting agree very closely with actual values obtained on tests. We have made some studies in the Alabama Power Company in connection with that, and find that that is true.

Most of the hoists in Alabama are slope hoists and they vary in length from a few hundred feet to some eight thousand. The grades vary from possibly 60 per cent down to very light grades. Also the grades found in the average mines vary.

In connection with the slope of the long-haul hoist, the trip is unbalanced in the pulling of cars. The return of the empty trip into the mine is usually done with a break. I would be interested in a discussion on the question of regeneration in such cases. We have found that such regeneration is possible and it returns appreciable percentages of power to the line.

In connection with the conduction of peaks on hoists, that becomes a matter usually to be determined between the consumer and the power company, if it happens to be purchased power, or in the case of a small power plant used to operate the hoist, a matter of not overloading a small plant; but particularly in the case of a power company, the demand applies, that is, a time limit, or in the case of almost all Alabama mines, a fifteen-minute demand period. You will have a certain number of cycles during that period, and the momentary peaks do not usually influence the total demand.

F. L. Stone: I think I may be able to throw some light on the question of regeneration. It is entirely feasible to regenerate with an induction-motor hoist, provided you let it go a little above synchronism. Many slope hoists are operating under those conditions, but strange to say, many power companies put a ratchet on the meter.

G. H. Finks: In connection with the regeneration, you say the power company might put a ratchet on the meter. Well, that is true. A mine usually has additional load to carry which can be carried on a hoist and the meter will tend to come to a standstill as the mine load is picked up by the regenerated hoist. We have noted that a meter will not reverse until the total load is carried on the hoist. Most mines have a large amount of pumping, fans, and stuff of that kind, which has to be carried before energy can be put back into power lines, but the energy that is used for operating ventilating fans and pumps must be paid for and puchased from the power company.

ILGNER WARD-LEONARD COAL MINE HOISTS.
KW-HR. PER TON

Feet Hoist	Mine No. 1		Mine No. 2		Mine No. 3	
	395		412		444	
	Tons	Kw-hr. per Ton	Tons	Kw-hr. per Ton	Tons	Kw-hr. per Ton
1915	785,492	.63	401,550	.70		
1916	836,948	.64	550,225	.68		
1917	724,552	.64	582,110	.58		
1918	761,929	.64	674,547	.69		
1919	594,416	.67	592,677	.65		
1920	745,330	.64	781,595	.55	169,583	1.04
1921	818,400	.57	767,852	.63	585,286	.76
1922	647,348	.60	673,074	.64	532,418	.71
1923	710,667	.59	802,274	.67	772,340	.75

1. A. I. E. E. Journal, Vol. XLIII, July, p. 618.

AUTOMATIC SUBSTATIONS FOR INDUSTRIAL PLANTS[1]

(Lichtenberg)

Birmingham, Ala., April 10, 1924

C. S. Butcher: One of the earliest installations of automatic equipment in industrial plants was in the motor car industry in Detroit, where two 1,500 kw. motor generators are used to augment the power supplied by a steam plant. The steam plant is located at one end of the manufacturing aisle, which is some 600 ft. or so long, and a very heavy bus runs through a tunnel from the power house to the load, which is distributed along the bus quite uniformly. It was found, in making a study of the power plant, that the steam costs were very high, however in the wintertime the exhaust steam is used for heating, and in working out the economics of the problem it was found that if substations were located along the bus, the steam plant, during the summer months could be shut down and considerable saving realized by purchasing power.

The first machine was installed in the summer of 1920 and consists of a shunt generator provided with a constant-voltage regulator. This very materially improved the voltage on the bus at that point, since it was more nearly in the center of distribution. As the plant grew, the next year a similar substation was added, and in that case we ran into our first difficulty of parallel operation. The machines, while being built for shunt operation, were, as I say, equipped with constant-voltage regulators and it was quite difficult for a time to get the machines to share the load. This was done by rather an ingenious device attached to each regulator. By the use of this device, the machines were given somewhat the characteristic of a straight shunt machine not provided with voltage regulation. The installation has been entirely successful and has since been followed by a great number of installations in the industrial field generally.

Mr. Lichtenberg starts out with the power plant, quite naturally, in the development of our natural resources. However, I don't like to think that we are going to limit automatic operation to the smaller sites; in fact, we haven't done so. We now have about ready to go into operation an 8000-kv-a. hydroelectric station, completely automatically operated, equipped with two 4000-kv-a. generators. That is not large in a sense, but in proportion to the capacity of that system, that really represents quite a large operation.

Previous to that, on the same system we installed a generating station equipped with two 2000-kv-a. water-wheel generators. On that particular property 4000-kv-a. would represent about 25 per cent of the total system capacity. However, inasmuch as all of that was not connected to the load, there were times when the automatic station would represent perhaps 50 per cent or better, of the total connected capacity.

The machines are of the older type and are not equipped with damper windings, and it was necessary to find some means for synchronizing the automatic machines with those already connected with the load. Most of you are familiar with the automatic synchronizers which were first used with the old engine-driven units. With the machines of larger capacity, no one liked to depend on the automatic synchronizer. However, with that as a foundation, we started out to make an automatic synchronizer. With that, we combined an automatic speed-adjusting device, which consists of nothing more than two little synchronous motors, one connected to the line and the other connected to the incoming machine; the two motors driving together a differential which operates to regulate the speed of the incoming unit by the operation of the speed adjustor on the governor mechanism. That, in combination with a modification of the old synchronizer, worked out beautifully, and that station has now been in operation for six or eight months and has been entirely successful.

1. A. I. E. E. Journal, Vol. XLIII, May, p. 411.

In connection with hydroelectric plants we are accustomed to thinking of large developments. Large developments often involve the condemnation of considerable portions of land in order to create the necessary storage capacity and to get the necessary head. That is done for the reason that by concentrating our power at any one point, operating cost is kept down to a minimum. If we eliminate the operating cost; that is, the labor of attendants, and develop that same head at a number of smaller sites, the same can be all automatically operated and connected to a common distribution system and operated with considerably greater economy.

Passing from the automatic hydroelectric station, we of course come to the automatic operation of a-c. feeder circuits. That equipment also is practically standardized and practically ordered by style number. The periodic reclosing equipment is perhaps the most common that is used. There are other special applications, but I will not mention those. The duty cycle on the breaker for periodic reclosing is more severe than the standard duty cycle; even the new one that has been adopted. For example, the power companies ordinarily apply this type of equipment to radial-type feeders and require that the first reclosing following an outage shall be on the order of thirty seconds. In case the feeder does not remain closed, it is closed again at the end of perhaps a period of a minute; the third reclosing taking place at the end of a period of approximately two minutes. At the end of that time, if the circuit is not closed definitely, the feeder is locked out of service. If, following any of these reclosures previous to the last one, service remains normal for a predetermined length of time, the equipment is automatically reset to zero. Therefore, the equipment is restored to complete service.

Coming down to the application of automatic substations for supplying direct-current load, we have the railway, light and power, and industrial. They perhaps pretty well cover the industrial; but just taking the railway, which has perhaps seen the greatest development in automatic switching equipment. That is where we started with the synchronous converter, which is probably the most difficult to control. I think most of us are quite familiar with some of the earlier developments which were applied particularly to interurban railways. A great many people at that time said, "Well, that's all right for small interurban roads where continuity of service is not required, but you will never see it on the larger systems." Well, it hasn't worked out that way.

At first we were forced to show a considerable saving in order to justify the installation of automatic switching, but it has been definitely proven that the operation of automatic substations is so much more satisfactory than the operation of manual stations, that automatic switching equipment is being installed now where continuity of service is of prime importance. The application of automatic substations to heavy networks, whether they are railway or light and power, is made not so much on what can be saved in operators' wages and the like, but what can be saved in distribution losses.

I have in mind our first application to Edison's load which was made in the City of St. Paul in 1920. There, a large theatre and office building was built on the very edge of the Edison three-wire, 250-volt network. To run cables to this point would have meant a large investment in ducts and in copper. It was absolutely essential, however, that they have good voltage regulation at this building, so they compared the cost of cable and ducts with the cost of an automatic substation. The economics were decidedly in favor of the automatic substation, but they were not quite sure that it would give them just the service they wanted. However, it was tried out. The inspection has been weekly, with a man visiting the station approximately twenty minutes each day, and all of the little things which might have caused a shutdown have been caught on inspection. So that station has never caused an interruption of service to that build-

ing. Several times the network has been lost and the station has automatically isolated itself from the system and supplied the isolated load.

F. M. Nash: In our concern we had occasion once to consider an automatic outdoor generating station, and I would like to ask if there are any here who know of, or can give any account of, the installation of automatic outdoor generating stations. In this particular instance we had to consider the replacing of three 1000-kw. machines with one automatic generator, outdoor type. The change was not carried out partly because of the cost and partly because of the uncertainty of such an undertaking.

C. A. Butcher: So far no automatic switching equipment; that is, complete automatic switching equipment, has been applied to an outdoor generator, and to my knowledge there has been built only one generator for that type of service. I am pretty sure that the Allis-Chalmers Company built that.

That problem came up a number of years ago and a study was made to determine whether or not it was feasible. It was determined quite definitely that it was feasible and also practical, but uneconomical, for the reason that the protection which must be afforded the generator and the generator housing would have to be of special design. The fact that there are very few applications for this class of machine, thus necessitating placing all the development costs on very few, made it an uneconomical proposition on the very few that we considered.

A NEW 20-16-IN. HOT STRIP MILL[1]

(Jones and Wilson)

Birmingham, Ala., April 11, 1924

Edward T. Moore: The only question that I would bring up would be the initial cost; whether the savings per ton would carry the additional interest on the increased investment involved in that type of mill over the ordinary installation?

G. E. Stoltz: There is no question but what that type of drive costs more than if a single motor were used, similar to that installed on the roughing train. However, the increased cost of the electrical apparatus, is offset by the fact that you can eliminate the lay shaft and beveled gearing, so that the mill cost is considerably reduced. But the thing which justifies that type of drive is the ability to roll steel that cannot otherwise be rolled.

There is one other advantage, and that is the fact that the steel is finished hotter, and takes less kilowatt-hours per ton.

MAXIMUM DEMAND REGULATOR FOR ELECTRIC FURNACES[2]

(Moore)

Birmingham, Ala., April 11, 1924

G. E. Stoltz: Mr. Moore has described a device here that will interest a good many people. I have quite frequently been asked if there was such a device that would prevent establishing a high demand peak, at the expense of the customer and also to the disadvantage of a power company since it must be able to serve this customer with these abnormal peaks.

In one instance which I have in mind, a new 40-in. blooming mill was installed and the motor and mill were ready to operate before this customer had his new turbine equipment installed, and the only way he could place this mill in operation would be to draw from the turbines already installed, and as they were loaded up almost to their capacity, it was essential to have some means of limiting the input to this new mill. In this instance the electric equipment consisted of a reversing motor and a flywheel set. The set took its power through an a-c. motor, and this motor was controlled by means of a liquid regulator. This liquid regulator at that time was set at 2500 kw., and at no time would the load exceed this value, although it would slow down the equipment at times when the operators would endeavor to roll at a rate that would tend to increase this demand. However, they soon became accustomed to this limitation and would roll accordingly. Today that same mill is taking a demand of 3750 kw. Recently I saw a twenty-four hour chart on this particular mill, where they had rolled some 500 ingots in twenty-four hours, and I don't believe the input to that motor during the rolling of each of those ingots varied very much over 200 kw., indicating that apparatus of this type and of this character can control the input very closely. I don't believe it in any way limits the output, although, as Mr. Moore states, for the time being if you limit the input to equipment, it will no doubt reduce the tonnage, but, on the other hand, we usually find mills that run spasmodically will have delays and periods of rest, and a device of this type simply controls the rate of rolling, keeps it regular, and usually reduces maintenance on machinery, which has operated at times at an excessive rate, while at other times the men were idle.

I have another instance in mind, where there is a blooming mill and a bar mill in tandem. This is practically all the equipment they have in this particular plant, so that they are not able to diversify their load. The open-hearth capacity is only about one-half of the blooming mill and bar mill capacity and they find the operators can roll for an hour or maybe half an hour at a very high rate, establishing a high peak, and then remain idle for the next half hour or hour. They installed a device similar to that described by Mr. Moore, which consists of a wattmeter element that closes the circuit to an electric lamp in the pulpit of the blooming mill, and when that lamp is illuminated, the operator knows that he is approaching a demand which should not be exceeded. Of course he would have to finish the ingot in his mill but would not call for another until this light went out.

The advantage, of course, to the power company is that they have a much more satisfactory load, and while they will deliver the same number of kilowatt hours, the same capacity of generating equipment will be able to serve a greater number of customers.

F. M. Nash: From the standpoint of a power company's operating department in our organization we welcome anything that tends to cut down a high peak and to give a more uniform load.

E. T. Moore: Mr. Stoltz mentioned that a wattmeter element is sometimes used in connection with a signal light, so that the operator may observe the signal light and curtail the load. This is a very common method of semi-automatically handling the demand, but we have found it unsatisfactory. Where the human element is brought into play, there is always failure in controlling loads. We have gone to the extreme of detailing a man to be stationed at our furnace, to watch the totalizing meter with instructions to cut the load on an individual furnace as occasion requires. We have never found that he could successfully concentrate his mind continually throughout the shift period every day in the month and prevent the occurrence of peak loads; and I don't believe it can be done. For that reason, it is very desirable to have entirely automatic means, so that when the demand value is reached, the load can be reduced to such a value as is necessary. Of course, the amount of cutting has to be predetermined with care. It would not be desirable to cut the load arbitrarily, say, 500 kw., if the demand value is only exceeding the predetermined value by, say, 200 kw., and the device has an inherent characteristic so that it will select just that value which it is necessary to cut, and only for the necessary period of time.

Central stations, I have found, are very much in favor of such a device, even though the amount of the power bill is naturally going to be less. They welcome any device which will cut down the excessive peak loads on any consumer's circuit, because it has the advantage, by so doing, of increasing the diversity which will exist between various consumers and helps in building up a higher load factor, which of course is very much sought after and simplifies the handling of the generating apparatus.

1. A. I. E. E. Journal, Vol. XLIII, August, p. 710.
2. Unpublished.

LIGHTNING ARRESTERS[1]

(BENNETT)

BIRMINGHAM, ALA., APRIL 8, 1924

E. E. F. Creighton: In Mr. Bennett's paper he gives a description of his attractive design of arrester. Mr. Bennett has properly put the question of theory and operation to this independent body,—the American Institute of Electrical Engineers. There are two devices and two principles involved; one principle depends on a tube of electrolyte, and the other principle is known as the "liquid electrode."

I am much more familiar with the original type of this tube arrester than I am with Mr. Bennett's particular design. In 1904 I worked with the inventor, E. S. Halsey (U. S. Patent 888,235). Since it fell to my lot to make the tests on this arrester in 1904 and later, I learned its characteristics. By 1906 I came to the conclusion that this type of discharger could not be made into a satisfactory arrester. To be sure, the theory of operation is simple and the materials of construction are cheap. In addition, the industry has been, and still is, in great need of an effective cheap lightning arrester. Consequently, twice since 1906 have we worked in vain on Halsey's invention in an endeavor to make an acceptable discharger of it. Failure was the bitter medicine we had to take. Nature's unchangeable laws play no human favorites. No more than we, could Mr. Bennett make a good conductor out of a cylinder of high-resistance liquid. To make the best electrolytes conduct electricity better than they do is similar to the insurmountable problem of making a better conductor of pure copper. On the other hand, if, in the design, the cross-section of the tube is increased to get better conduction by greater cross-section of electrolyte, the power current cannot be interrupted by the tube. As a result the arrester is destroyed. So much for the fundamentals of operation.

Briefly put, there are two main reasons why this device cannot be called satisfactory. First, its maximum possible discharge rate of lightning current is too small to be of appreciable service. Second, when the power current follows the discharge across the series gap the power current forces the liquid out of the insulating tube and thereby opens wide the circuit. There is a gap of two or three feet equal to the length of the tube. Until the electrolyte runs back into the tube (requiring about a half-second) there is no discharge path for lightning. The defect is evident. It is usual for thunder-clouds to produce several lightning discharges in quick succession. In the Colorado tests in 1907 I found as many as seven successive discharges within a period of one second.

The foregoing statements cover essential fundamental characteristics of an arrester. Both low discharge rate and open circuit destroy the usefulness of this device. There seems to be little point in discussing the quickness of discharge of any gap in series with the tube of high-resistance electrolyte because a surge would not be relieved through the resistance if the gap were metallically short-circuited. There is much about cloud lightning and its effects that is unknown. Nevertheless, the factors herein condemned are as firmly established as anything can be in this difficult field.

To decide the value of a type of arrester by actual service involves complex factors not easy to determine. My experience indicates that a service test can be relied upon only by the use of a great many arresters, installed under various conditions of circuit, and carefully observed over several years.

In the later type of arrester described by Mr. Bennett the principle of operation involved is known as the "liquid electrode." It is possible to use this principle to obtain high rates of discharge of lightning and yet decrease the rush of power current, which follows, to a reasonable value. The reduction of power current is made possible by the absorption of about 2000 volts at each liquid electrode. The counter-electromotive force of these arcs in series may be used in sufficient number to reduce the power current to zero.

A. L. Atherton: Throughout all discussion of lightning-arrester performance, we find a wide difference of opinion. One operating man finds one kind of installation to be right, one system of protection to be best; the use of lightning arresters to be proper; another operating man finds altogether different conditions and use to be the right ones, and sometimes altogether to eliminate lightning arresters to be the right practise. We go all the way from no justification for arresters to the use of arresters on every transformer; and we go all the way through the large number of possible varieties of methods of installation of the arresters, all of which simply shows that you have to consider the whole lightning arrester question as one grand average.

There has been, in the history of the lightning arrester study, one outstanding, complete, long-time investigation of results secured with lightning arresters from accuartely tabulated and closely analyzed results. I am referring to the study made in Chicago on the distribution system of the Commonwealth Edison Company by Mr. Roper, the results of which were presented to the Institute in two or more papers, the latest one in 1920. Mr. Roper got out of his whole study an average conclusion to cover average conditions, but this came from "shot-gun" data. The conclusion which was established in a way which was accepted by practically every one was: That as you increase the density

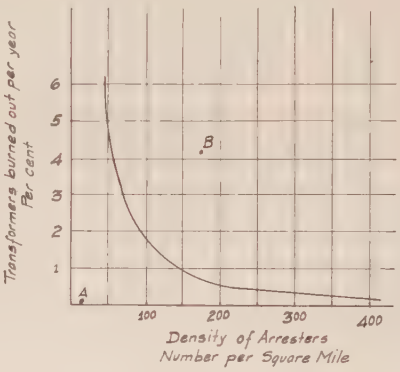


FIG. 1

of lightning arresters over a system, you reduce the troubles. That has been verified more or less indefinitely in other cases.

On the other hand, Mr. Roper found that in local areas, even with as high as two or three hundred arresters in a single square mile, the point for a full year fell way off the curve. If you refer to the printed results, you will find a condition like this: The curve of average results was, as in Fig. 1, and yet there were points as at A and B. These isolated points are the only kind of experience that an operating man can establish on a high-voltage system, because the number of transformers involved and the densities of transformers on his lines is quite radically below that necessary for a full curve.

I am stressing this point because we have two methods of presenting a lightning arrester question this morning. Throughout the past years there has been a good deal of effort and attention put on the general problem of estimating what lightning conditions are, and what must be done to take care of them, and these studies—mathematical analyses, field studies, laboratory tests—involving the efforts of a considerable number of men, over many years, has resulted in the establishment and acceptance, by those people closest to the problem from the study standpoint, of certain definite, basic facts—not definite in the sense that they can be expressed in precise figures, but definite in the sense that they are basically right.

On the other hand is service experience.

The papers by Mr. Young and Mr. Bennett approach the

1. A. I. E. E. JOURNAL, Vol. XLIII, September, p. 791.

question from the two different viewpoints. Mr. Young accepts the established facts and studies performance in relation to them. Mr. Bennett depends almost wholly on service results, which are of very small volume when considered in the light of Mr. Roger's 200,000 arrester-years study and of his irregular points of 1000 or so arrester-years.

If Mr. Bennett's results disagree, as they seem to, with the established ideas, and if we accept them, we must do so with the realization that we are casting aside the results of all previous work. The evidence is, in my mind, far too slight to justify such a move.

One thing I would like to bring out in connection with Mr. Young's studies is this—I think it was touched on by Mr. Creighton: That whether we can depend as a close percentage value on the test results that are given, whether we believe that 32 per cent, 24 per cent, and whatever the other figures may be, represent a relative evaluation of the arresters, it seems to be clear that if you do apply surge voltages or short-time over-voltages to an arrester, and if you do get large currents in one case and small currents in another, then you have some evidence. It may not be accurate. From my experience in trying to get accurate evaluation of arresters, it is not accurate. Nevertheless, where you get wide differences in results, you show a difference in performance, and although the percentages canno tbe accurately depended on, they should he depended on to the extent of showing some relative evaluation.

K. B. McEachron: The Bennett arrester is a resistance-gap type arrester with a circuit interrupting scheme which is ingenious. The purpose of the gap is to connect the resistance in circuit when a certain predetermined voltage is reached.

Since the resistance is composed of a weak solution of high resistance its conductivity is the same under high-voltage steep-wave-front conditions as it is at low voltage 60 cycles. Although it is undesirable that the resistance should increase with impulse voltages it is desirable that it should decrease, which is the condition with some of the gap-resistance-type of arresters whose impulse resistance is but a fraction of the low-voltage resistance. This decrease in effective resistance is found in all of the valve types of arresters such as the aluminum, auto-valve, oxide-film, and pellet arresters, and is a very desirable characteristic. The Bennett arrester has appreciable time lag due to the use of high resistance in series with the gap. In addition it has sufficient resistance so that a high instantaneous voltage is required to discharge moderate currents through the resistance of the electrolyte. This means a low discharge rate and a high instantaneous voltage. As the resistance is reduced the impulse characteristics are improved, but the disturbance to the circuit becomes greater. There is a practical limit beyond which it is not desirable to decrease the resistance.

Such an arrester does have large heat-storage capacity which is not needed in a lightning arrester provided the dynamic current flow through the arrester is prevented, as in the case of valve types. In the event of arcing grounds or accidental application of over dynamic voltages, heat-storage capacity is desirable. At the same time a high discharge rate at a safe voltage above line potential is of great value in that protected apparatus may be saved from damage. This feature is found in certain of the valve type arresters, combining as they do, moderate heat storage capacity with high discharge rate and safe instantaneous voltage.

H. M. Towne: Since the active element of the arrester is chiefly water, the author is certainly not to be censured for careless use of rare and expensive materials. However, the analysis of a design of lightning arrester involves the question of electrical characteristics of materials as well as their cost.

In considering the use of water as a conductor in an arrester discharge path, we must be very careful not to over-rate the actual value of water as a conductor to lightning and high frequencies. The fact that the current penetration in a water column is much greater than in a copper or other conductor of equal cross-section does not in itself justify any fallacious impression that water has any magic properties for conducting lightning currents.

The high-frequency resistance of a conductor is directly proportional to the square roots of the resistivity, the permeability, and the frequency. The penetration of current is directly proportional to the square root of the resistivity. The resistivity of river water varies widely, probably between 6000 and 20,000 ohms per cm^3. A salt-water solution has lower resistivity depending upon the per cent of saturation. Salt water becomes a saturated solution when 26.5 per cent salt by weight is dissolved in the water (20 deg. cent.). The resistivity of saturated salt solution is 5 ohms per cm^3. The resistivity of copper is 1.6×10^{-6} ohms per cm^3. Therefore, for a conductor of given cross-section, the saturated salt solution will have a low-frequency resistance of 3,000,000 times that of a copper conductor. This ratio becomes less with increasing frequencies because the penetration in the copper conductor is not complete. For instance with a No. 10 copper wire, the penetration at 10^6 cycles per second is only 2.5 mils. This means that only a tenth of the total cross-sectional area will carry current and so the effective high-frequency resistance of the wire is ten times its low-frequency resistance. Therefore, while the low-frequency ratio of resistance between the saturated salt solution and copper is 3,000,000 to 1, the high-frequency ratio of resistances is 300,000 to 1. In order, then, to increase the saturated salt solution to the same conductivity as the No. 10 copper wire, the cross-sectional area of the solution must be 300,000 times that of the wire. Since the cross-sectional area varies as the square of the diameter, the water solution will have to have a diameter of $\sqrt{300,000}$ or 550 times that of the No. 10 wire. This means that the saturated salt solution column must be 4.65 feet in diameter to make it equivalent to a No. 10 copper wire.

The comparison is better appreciated if we consider a 0.4 per cent salt solution by weight which is claimed to be as near saturation as is possible to use in the author's arrester. The resistivity of a 0.4 per cent salt solution is maybe taken as 150 ohms per cm^3., which is 30 times the resistivity of the saturated solution. Therefore, the cross-sectional area of the 0.4 per cent solution column must be 30 times that of the saturated solution column. The diameter of the 0.4 per cent solution column must be the $\sqrt{30}$ or 5.47 times the diameter of the saturated solution column. The result is that we require a 0.4 per cent salt solution 25.4 feet in diameter to be equivalent in conductivity (at 10^6 cycles) to the little No. 10 copper wire.

Extending the illustration still further, pure river water with a resistivity of 10,000 ohms per cm^3. would require a cross sectional area for the column 2000 times greater than that of the saturated solution. This means that the diameter of a river water column would be $\sqrt{2000}$ or 44.7 times the diameter of the saturated solution column. Then the column of river water must be 208 feet in diameter to be equivalent in high frequency resistance to the copper wire 0.1 inch diameter.

Still further illustration may be interesting. The author claims to use a salt solution of not over 1½ per cent saturation; *i. e.*, 0.4 per cent solution by weight. The resistivity of a 0.4 per cent salt solution is approximately 150 ohms per cm^3. Considering the diameter of a column of this solution to be 2 in., its equivalent as a conductor of lightning would be had by substituting a copper wire 0.00023 in. in diameter. To be sure, the author does not propose to use a ¼ mil wire, but from the standpoint of high-frequency resistance such a wire is equal to a 2 in. dia. salt solution column of 1½ per cent saturation.

In the foregoing, I have tried to point out that while the penetration of current in a conductor has considerable influence upon the high-frequency resistance, its influence is quite negligible

when compared to the influence of resistivity. In reality a water tube of water column is among the poorest of lightning conductors and should be avoided in lightning arresters. With a 0.4 or less per cent salt solution column 2 in. in diameter and 2 or 3 feet long, the resistance represented becomes a question of thousands of ohms in the discharge circuit. This gives very limited discharge rate. With a 3000-ohm salt-water resistance between the arrester gap and ground, only a 100-ampere lightning-discharge current would produce an $I\ R$ voltage of 300,000 volts across the arrester, with corresponding dangerous stress on apparatus insulation. The use of more saturated solution would improve the discharge rate but cannot be used without impairing the ability of the arrester to interrupt the dynamic current. Even with the high-resistance solution ordinarily used, 10 to 40 cycles are required to interrupt the dynamic current. These limitations form a striking contrast to the valve types of arresters which allow very large discharge rate with practically no dynamic current following the discharge.

The question of interruptions to the continuity of an arrester discharge circuit is of vital importance and so it is difficult to reconcile the time period that the author's arrester is in a non-conducting state while the water column is returning from the down position to the up or closed-circuit position. The minimum time required for the column to be forced up to its normal position by the head of salt water in the tank may be calculated, and this calculation agrees with the oscillograph in indicating from 0.3 to 0.8 second, depending upon how far the column is forced down before the arc is extinguished. During this period the arrester is inoperative. Overvoltages occuring on a line in very rapid succession such as produced by the multi-lightning flash or arcing grounds would stand a pretty good chance of catching the arrester off duty. Oscillograms show no conduction through the gases or vapors in the arc chamber while the water column is down.

Of course, it is true that a large volume of water has considerable heat-storage capacity which becomes very desirable when a lightning arrester is subjected to long continued discharges due to over dynamic voltage. Obviously if the resistance of a discharge path is kept low and the duration of dynamic current flow either eliminated entirely as in the valve types of arresters or confined to one or two half cycles, the $I^2\ R$ energy will be insignificant. Lightning discharges without dynamic energy through an arrester of low resistance will produce entirely negligible heating. For instance, a 1000-ampere discharge through a 10-ohm resistance represents 10,000,000 watts, but assuming the time period of the discharge to be about 10 micro-seconds, the energy represented is only 100 watt seconds. This would call for no cooling coils or other means of heat dissipation.

The question of reduction of arrester gap spark potential by rain has been a serious factor in over-voltage protection until several years ago when the development of the dry type valve arrester permitted the use of the covered or shielded sphere gap. The covered sphere gap seems to be the only possible method of obtaining uniform spark-over values for all weather conditions, on outdoor arresters. The covered sphere gap is not practical with any arrester with which there are dynamic arcs to be broken and therefore they have been used with only the modern valve types of arresters. There is practically no advantage to be gained at the lower voltage settings with the so called compensated gap, over the exposed sphere gap under standard precipitation. Furthermore, at the higher voltage settings the compensated gap approached the needle gap in its characteristics. The wet and dry spark potentials of a needle gap are approximately equal but it is well established that the needle gap has serious time lag. While the compensated gap is an ingenious device, and represents a commendable effort, it falls short of being an ideal lightning-arrester gap which should combine equal wet and dry spark potentials with maximum speed.

C. E. Bennett: Prof. Creighton brought up several things at this meeting about the arrester that I would like to answer.

First of all, I am glad he refers to the Halsey patent and gives the number of it so that anyone can look up this patent and see how essentially different it is from the form of arrester described at this meeting. Anyone can see at a glance that the devices are not similar in any detail and the principles which we have used are entirely remote from the Halsey patent.

Mr. Creighton speaks of the low discharge rate of the Bennett arrester. He has overlooked the most essential feature of the arrester, in that it is a combined condenser and resistance in multiple, and that is why this type is new as compared with the old Halsey arrester, which of course was a failure from the start.

The discharge rate of this arrester is low at 60 cycles, but let us assume that on a 20,000-volt installation, a voltage of five times line voltage and at 500,000 cycles per second, the arrester will have a discharge rate of 88 amperes, against 10 amperes at 60 cycles, which is an ideal design for an arrester.

It is unfortunate that Prof. Creighton would criticise functioning of this device without apparently being familiar with the design and operation of this apparatus. How can the water in the tube be driven down two or three feet when a number of the designs have tubes submerged only 34 in.? If the water is driven down through the tube the arc would probably follow and you would have practically a dead short circuit across the arrester. In fact, on the 84-in. tube the water is ordinarily driven down the tube from 6 to 10 in.

Then he says it takes half a second to interrupt. We have oscillograph records to prove that this contention is not true, but that the dynamic current is broken in less than a half cycle when dynamic current flows through the arrester, but the path to high-frequency or impulse potential is always continuous through the tube. The above time is referred to 60 cycles per second.

If any type of arrester were out of service eight or ten seconds, or even cycles, it certainly would be useless. but we have made a great number of tests and observations of the Bennett arrester by the use of glass tubes, tanks, etc., and have found that when induced charges of approximately 70,000 kilocycles were superimposed on 60 cycles and continuously applied, at no time did the interrupter fail to protect shunted air or oil gaps, which proves conclusively that the conducting vapors in the tube are always ready to function and form a continuous conducting path regardless of the moving liquid level.

In these arrester discussions we are confining ourselves to induced voltages and not to direct strokes. These induced voltages only represent about two to four kilowatt-seconds of energy, and, therefore, only a small mount of energy must be drawn off by the arrester.

Another thing, I think the question of high discharge rate is not so important as that of the desirability of more frequent installations of lightning arresters whose discharge rate does not approach a short circuit. As an example, if our line supports were of comparatively high conductivity, impulses and super-potentials would soon be drained off and dissipated and would rarely reach the end of the line. Open aerial telephone circuits are subject to practically the same super-potential and exposure that transmission lines are, but the insulators are frequent and of relatively high conductivity, and as a result the induced potentials are held down. So if we had arresters of comparatively high conductance at each point of support on power lines we would have nearly perfect protection against superimposed induced potentials but of very difficult operating characteristics.

Concerning the time lag referred to in Mr. Young's paper, I think that if he had made tests on different types of arresters in parallel with impulse potentials, he would have found some very interesting results. We have done this by the use of parallel

gaps and then have switched the gaps about so that each type of arrester would be tested under the same conditions, and I believe this is the only satisfactory way to prove the speed of any type of gap.

In the design of any arrester the heat-absorbing characteristics are essential at times when arcing grounds and continuously applied induced voltages occur on transmission lines. It is safe to set the gaps down to a point of, say, 25 per cent above line voltage for normal operation and if an arcing ground occurs the arrester will hold on to the arcing ground for a long interval and drain off the potential. Arresters made of materials of low specific heat value must naturally be set at a higher initial sparkover voltage to prevent continuously applied potential causing excessive heating and eventually destroying the arrester.

Regarding Mr. Towne's figures, I do not see wherein they have much to do with the theory of this lightning arrester or the operating characteristics or its protective ability.

Now, on the question of the gap, something was said about it having different characteristics at high voltage from those it has at low voltage. All that need be said about this is that the curves submitted in the paper, Fig. 7, were actually obtained by comparison with sphere gaps in one of the best equipped industrial electrical laboratories by disinterested operators.

EFFECT OF CERTAIN IMPURITIES IN STORAGE BATTERY ELECTROLYTES[1]

(Vinal and Altrup)

Birmingham, Ala., April 11, 1924

H. M. Gassman: I would like to ask a question as to whether any experiments, including the effect of uranium salts in electrolyte, have been made?

G. W. Vinal: We have not as yet made any experiments with uranium salts. We have made experiments with some of the unusual impurities, such as tungsten. We hope to include quite a wide variety of these impurities later.

H. M. Gassman: The reason I asked that question was because I understand that is the active component of some of these revivifying solutions of electrolyte.

Mr. Vinal: I have seen some of them that are supposed to contain uranium, but I don't know that uranium really does much.

These advertised solutions may really be classified under three heads, so far as our experience goes. The first is ordinary sulphuric acid, to which is added some coloring matter. The second class contains substances which are supposed to retard sulphation. Some people still have the idea that sulphation is an unmitigated evil. As a matter of fact, if the battery didn't sulphate, there would be no discharge. The third class of impurities are those which are active corrosive agents and eat into the plate and grids.

Discussion at the Worcester Meeting

REPEATED THERMAL EXPANSIONS AND CONTRACTIONS[2]

(Taylor)

Worcester, Mass., June 5, 1924

F. D. Newbury: Operating engineers have often raised the question of the possible effect of extreme expansion and contraction in long cores, and this series of experiments, which lasted something over two years, was started in an attempt to find a quantitative answer to that question.

Since this is a laboratory model test it is, like all other model tests, open to the criticism that it does not represent all of the conditions met with in actual service. However, it does do this—which is the advantage of working with models—it confines the experiment to one condition: In this test the one condition has been the expansion, the relative movement of the conductors with respect to the outer layers and the cores adjacent to the insulation. I should like to call your attention to one point and that is that the temperature difference that we are interested in here is the temperature drop through the insulation. It is not necessarily the temperature rise of a generator. We may have a generator with a 60-degree rise, and a 30-degree core, resulting in a 30-degree drop through the insulation. From this standpoint of positive deterioration of the insulation, that generator would have the same effect as another generator having double the rise and the same 30-degree drop through the insulation, the higher rise being due wholly to a higher temperature.

Operating engineers have also pointed out erroneously that a low temperature rise is necessarily safer from this standpoint of heating and cooling. That is not necessarily true. It is only safer when there is a lower drop through the insulation.

So, as I say, the important temperature difference that we are interested in is the difference in temperature between the conductor and the core or outer layers of the insulation.

In these experiments, the length of the test core was 109 inches. The temperature drop, however, began with 75 degrees, as you will notice from the table on the third page of this paper and was increased gradually, as our courage increased, up to 160 degrees.

We are considering generators that may possibly have double this core length. But since the difference in temperature is more than double that ordinarily met with—that is, the drop through the insulation will rarely be greater than 40 degrees, and frequently as low as 30 degrees, even in 13,000-volt machines—we have really covered the extreme case that we will be concerned with in practise for the next few years anyway, that is, a core length approaching 200 in., but a temperature drop in the neighborhood of 40 degrees. We have here half the core length, but more than double the temperature drop.

In a way the tests were disappointing in that the results were entirely negative. We had expected to develop differences in the various types of insulation employed. For example, some of the types have flexible—what we call "slit" joints between the conductors, considered as a body, and the insulation layers outside of that intermediate flexible slit joint.

But all of the coils, however different in structure they were, showed equally good results, so that while from that standpoint the results were negative and disappointing, from the designers' and operators' points of view, the tests, I think, have been very reassuring in that no failures were obtained from this effect of expansion and contraction, even under those extreme conditions.

T. S. Taylor: In regard to the question as to why the mica-tape coils are more difficult to remove than mica-sheet coils, I think it is perfectly obvious why they should be, because a mica-tape coil is formed by hand and is not wrapped as tightly as the machine-wrapped coil. And, in addition to that, the coils were necessarily pressed down to size, and the cell in which they were finally placed, that is, the cell surrounding the mica-tape coils, was not of sufficient strength to prevent their swelling outward. As a matter of fact, they were more difficult to insert in the slots than the others were, and consequently, the fact that they were more difficult to remove is what we would naturally anticipate from the nature of the two kinds of insulation.

There is one point I might mention in regard to insulation in general, and that is the influence of temperature. I think we

1. A. I. E. E. Journal, Vol. XLIII, April, p. 313.
2. A. I. E. E. Journal, Vol. XLIII, November, p. 1047.

all realize that temperature itself does not hurt the electrical properties of insulation unless it gets to a point where you change the nature of the insulation. As a matter of fact, you can heat very poor insulation until it reaches the carbon state, and you will have very little breakdown, as long as it is intact. To be sure, if in this process you cause a crack in your insulation, then you are substituting an air path for insulation; consequently, you will have a breakdown. But this shows that even after these contractions and expansions which amounted to five millimeters at one end, maximum change, no breaks had occurred in the insulation of any one of the eight coils.

SHORT CIRCUITS OF ALTERNATING-CURRENT GENERATORS[1]

(Laffoon)

Worcester, Mass., June 5, 1924

V. Karapetoff: We may say, with fair assurance, that the problem of short circuits in synchronous machinery, and for that matter, in induction machines, will be with us for some time to come. The means so far used for representing these phenomena have been either cumbersome or insufficient, and I believe it is time for us to decide that in the question of short-circuits we ought to go back to the very fundamental physical facts. Let us begin our treatment not with some secondary laws, such as were admirably presented here, but with primary laws in the existence of which we have not a shade of doubt.

I have been lately working on the problem of short-circuits, beginning with the fundamental equations of induced voltages, and hope to communicate to the Institute later the results of my studies, from which short-circuit currents under many practical conditions can be derived from the same general expressions.

C. M. Laffoon: It is very gratifying from a theoretical standpoint to know that Prof. Karapetoff proposes to develop a complete mathematical analyses of the short-circuit phenomena of synchronous and induction machines. However, from a practical standpoint, it is not essential that the analytical and mathematical calculations be carried to any greater degree of accuracy than that which can be obtained, in determining the physical constants of the electric and magnetic circuits.

TORQUE PULSATIONS IN SINGLE-PHASE MOTORS[2]

(Alger and Kimball)

Worcester, Mass., June 5, 1924

C. A. M. Weber: I just wish to mention two experiences I have had in connection with this phenomenon a number of years ago. The final solution of one of these experiences does not conform to what Mr. Alger has just said and I would like to have an explanation from him.

Quite a number of years ago we had an application of a motor driving its load through a semi-flexible coupling, the load possessing a certain amount of inertia. With light load there was a distinct rattling set up in the coupling. We determined that the rattle was in the coupling by making couplings of lead and of fibre and the noise departed. We finally succeeded in making a successful motor by changing the design. We made two important changes in the design of the motor. First—by putting more iron into the motor which would be the same as reducing the voltage which in turn would reduce the amplitude of the vibration as brought out by the authors. The other change had to do with the proportions of the slots and the proportions of the secondary winding. These changes produced a motor which successfully operated the driven device without rattling the coupling.

In the other application I have in mind (a different kind of application using a ¼-h. p. motor, the other case used a 1/10-h. p. motor), the vibrations in the coupling were severe and we tried a number of ways to overcome these vibrations by increasing and decreasing secondary resistance without effect. This result is in agreement with the authors. However, we finally did succeed in eliminating the vibrations, that is in reducing them to such an extent that they were not noticeable by changing the proportions of the motor by changing both the primary and secondary slots and naturally also the secondary resistance to a certain extent.

I might also mention that we tried the effect of a fly wheel on the rotor assuming that the angular velocity would be maintained more nearly constant by means of a heavy fly wheel. We extended the shaft on the end opposite the application end and put a fly wheel on this shaft which, as I remember it, had a fly wheel effect about five times that of the rotor. We found that the noise was not reduced by adding the fly wheel.

These are the only two cases that I can think of now that stand out. We had a number of other ones which were easily overcome by slight changes in design.

The authors have discussed mounting. One mounting described is one that has been used by a number of piano manufacturers for the motor mounting. The one I have in mind has extended bearings on each end of the motor and mounts these bearings in felt-lined trunnions. The motion of the stator is damped by means of a piece of felt fastened to the frame of the motor and allowed to rest against the base supporting the trunnions. This is a large piece of felt and as you can readily appreciate would absorb the frame vibrations by permitting a slight movement as described by the authors. This mounting reduced the noise to such an extent as to make the motor suitable for very high-grade grand pianos.

F. D. Newbury: This question of pulsating torque and vibration in single-phase machines becomes a very serious problem in large machines, usually in connection with frequency converters for single-phase railway loads. While in the small motor, this pulsating torque is objectionable because of the noise it produces, in the large machines it is the vibration itself that causes trouble.

I have in mind some 5000-kv-a. 500-rev. per min. single-phase generators in which the vibration was so serious that bricks were shaken out of the building walls. In another case, the switchboard panels vibrated so greatly that the instruments could not be kept in workable shape. While this vibration has been encountered in relatively low-speed machines, it is not present, in any objectionable degree, in corresponding sizes of turbo-generators at 1500 rev. per min. For example, single-phase turbo-generators have been built up to approximately 15,000 kv-a. at 1500 rev. per min., without any objectiomable vibration, while a 3000-kv-a. 300 rev. per min. single-phase generator vibrated so badly that remedies had to be applied.

The solution in the case of large machines is the same as that arrived at by the authors and mentioned by Mr. Weber, but naturally it must be applied in a different way. In large machines we have found no way of supporting the frame either flexibly or by any form of spring support, except by a support that is in a plane tangent to the circle of the frame, and on the horizontal center line of the machine so that the action and reaction results in up-and-down motion that has no horizontal component.

In a machine of approximately 3000 kv-a. 300 rev. per min., the springs required are of alloy-steel bars about 7 in. thick, 5 in. wide and some 26 in. long. So if they were seen apart from the machine they would not look like springs. But they do function exactly as springs and can be calculated quite accurately, knowing the variation in torque and the characteristics of the spring. In this 3000-kv-a. machine, which has such a type of support, and is in operation, the vibration is noticeable up to about 500 kv-a. because up to that point the spring is not deflected. But above that point the springs come into play and the vibration at greater loads is no greater than at the very low loads which in this case is negligible.

1. A. I. E. E. Journal, Vol. XLIII, December, p. 1142.
2. A. I. E. E. Journal, Vol. XLIII, December, p. 1142.

Mr. Summers: In any problem where complex algebra is used to obtain results, it should be borne in mind that the method is fundamentally weak on account of the fact that the two axes are not symmetrical. For example, a quantity on the complex axis is squared, and it will have a negative sign introduced into it; while a quantity on the real axis will not.

Therefore, as Mr. Alger points out in his paper, it is sometimes necessary to reverse the sign on one of the complex quantities in the multiplication.

This fact is, of course, well known, though perhaps not as generally recognized as it might be, and for that reason, I wish to recommend that the engineers who have occasion to use analyses of this kind seriously consider the advantages of vector analysis, in which the vector quantities on the two axes are symmetrical and in which the product of the voltage and the current, if expressed vectorally, will give a correct answer in the form of power, without reversing the sign of one of the complex quantities.

S. S. Hertz: The point that Mr. Newbury brought out, that of the effect of the torque pulsations being not so noticeable on higher speed rotors, indicates that that vibration is a function, of not only the inertiz of the stator, but also of the frequency of those pulsations, and I wish to ask Mr. Alger and Mr. Kimball whether any experiments were made by changing the weight of the stators on the small motors, or, if possible, carrying the speeds up higher to see just what happens in small motors when those two values are changed.

P. L. Alger: Mr. Weber mentioned two cases in which he cured the trouble, to some extent, by changing the design. As I understand it, in both cases he changed the number of slots in the machine. By so doing it is quite possible he could change the magnetic noise and vibration of the kind that would be present in both two-phase and single-phase machines. The machine I am exhibiting, you will notice, has a very high-pitched note. That note is due to the fact that it has an odd number of slots on one side and an even number on the other side; consequently, it has an unbalanced magnetic pull, due to the fact that at the top one tooth is opposite another tooth, while at the bottom a tooth is opposite a slot. By changing the design, that noise can be very considerably reduced.

So in the cases he mentioned, I believe that the major change made was in the tooth-frequency noise rather than in the torque noise.

The second point, that Mr. Newbury brought out, was the fact that high-speed machines are relatively immune to the trouble, whereas low-speed machines have it very severely. I think that is due to the fact that the energy in the mganetic field of a low-speed machine bears a much greater proportion to the total energy supplied in one cycle than it does in a high-speed machine. That is to say, the magnetizing current of the high-speed machine is inherently a small part of the total current, while in the low-speed machine the reverse is true. This effect of a relatively small pulsating torque in a high-speed machine is accentuated by the high inertia of such a machine due to its great core length. The frequency of torque pulsation is, however, twice the line frequency in all cases.

A. L. Kimball: When the amplitude of torque pulsation is constant the angular amplitude of axial vibration of either the rotor or the stator is inversely proportional to its moment of inertia. Increasing the inertia of the rotor correspondingly decreases its vibration amplitude without affecting that of the stator. This was demonstrated by measuring the axial vibration of the stator with and without a fly-wheel on the rotor as described in the paper.

Regarding Mr. Weber's comment that the application of a fly-wheel to the rotor had no effect in decreasing chattering in the coupling, this is contrary to what we should expect from the results of our experiments.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

ARTIFICIAL ILLUMINATION IN THE IRON AND STEEL INDUSTRY[1]

At the annual convention of the Illuminating Engineering Society in September 1923, Mr. W. H. Rademacher[2] presented a paper of which the title is given above. Prior to its preparation, the author made an investigation at 12 of the leading steel mills located in Pittsburgh, Youngstown and Chicago districts. He had also available information from previous investigations, notably a similar survey made in 1911.

He classified the processes and locations and noted indications of particular lighting requirements. Table I shows a classification as regards the fineness of vision required.

TABLE I

Classification of Iron and Steel Mill Work with Regard to Visual Requirements

Rough	Medium Rough	Medium	Fine
Yards	Blast Furnaces	Chipping	Tin Plate Sorting and Inspecting
Thoroughfares	Cast Houses	Cold Rolling	
Stock Houses	Mixing Houses	Close Shearing	
Open Hearths	Bessemer Sheds	General Inspection	
Soaking Pits	Stripping Sheds	Wire Drawing	
Reheating Furnaces	Blooming Mills	Pipe Threading	
Puddling Furnaces	Structural & Rail Mills	Nail Making	
Annealing Furnaces	Rough Shearing	Picking	
	Rod & Tube Mills	Tinning	
	Hot Sheet Mills	Machine Shops	
	Cooling Tables	Power Houses	
	Warehouses		

Two general considerations are pointed out which tend to increase the demand for light in the iron and steel mills as compared with other mill processes. First, most of the objects are of low visibility due to their dark color and the darkness of their surroundings. Because of the small proportion of the light reflected by such surfaces, stronger illumination is necessary to reveal them and thus avoid hazard.

The second condition results from the presence of incandescent metal in process of manufacture. This constitutes intermittent and moving light sources which are quite brilliant, and become sources of glare. Unless the surroundings are fairly bright, the eyes have difficult adjustments to make. "The wider the contrast in intensities, the greater the degree of re-adjusting and the longer the time required by the eye to adjust itself * * * "

Since 1911 there has been a decided trend toward higher levels of illumination. Only a few of the lowest values found in 1923 were of the same level as recorded twelve years previously[3].

Table II compares the levels found in 1911 and 1923 surveys and includes the author's recommendation as to illumination for each of the principal processes.

1. *Transactions*, I. E. S., November 1923 (Vol. XVIII, page 824).
2. Lighting Service Dept., Edison Lamp Works of G. E. Co.
3. *Proceedings* of A. I. & S. E. E. 1911; Illumination of Iron & Steel Works, C. J. Mundo.

The variation in the practice found in the 1923 survey, has led the author to class the results in two groups namely, a low level group and a higher level group—the latter representing the newer or more liberal installations.

Of all the plants investigated, only three had illumination of a high order. In almost all, however, the equipment for general lighting was fairly good. High wattage lamps with reflectors were used, but they were not spaced closely enough to give an even distribution of light. The local lighting equipment was less well chosen, and in many places it consisted of bare lamps on drop cords. One of the chief defects in the systems was the practice of operating lighting circuits from direct current power feeders. The changing load on the circuits makes severe fluctuations in voltage which result in flickering light.

TABLE II

COMPARATIVE IRON AND STEEL MILL LIGHTING INTENSITIES

Process of Area	Foot-candle Intensity 1911 Average	Foot-candle Intensity—1923 Average Low	Foot-candle Intensity—1923 Average High	Foot-candle Intensity Recommended
Thoroughfares	0.087	0.02	0.3	0.1–0.5
Ore Yards	0.19	0.2	0.3	0.1–0.5
Loading yards (no inspection)	0.14	0.2	0.4	0.25–1.0
Loading yards (inspection)	0.36	0.5	0.75	0.25–1.0
Open hearth mould yards	0.29	0.2	0.4	0.25–1.0
Stock houses				0.5–1.0
Open hearth charging floor	0.14	0.3	1.5	1.0–2.0
Open hearth casting floor	0.17	0.5	1.5	1.0–2.0
Soaking pits		0.15	1.5	1.0–2.0
Reheating furnaces	0.46	0.3	3.0	2.0–4.0
Puddling furnaces				2.0–4.0
Annealing furnaces		0.5	3.5	2.0–4.0
Blast furnaces	0.25	0.4	0.7	1.0–2.0
Cast houses	0.22	0.5	1.0	1.0–2.0
Mixing houses				2.0–4.0
Bessemer (converter houses)				1.0–2.0
Bessemer (blower's platform)		2.5	4.0	3.0–6.0
Ingot stripping		0.4	1.0	1.0–2.0
Blooming mills	0.32	0.5	2.0	2.0–4.0
Cooling tables				2.0–4.0
Rail and structural mills		0.5	2.0	2.0–4.0
Pipe and tube mills	0.3	0.5	1.5	2.0–4.0
Chipping		3.5	7.0	4.0–8.0
Hot mills	0.34	0.75	3.5	2.0–4.0
Cold rolling	0.65	1.5	5.0	4.0–8.0
Shearing (close)		1.5	11.0	8.0–12.0
Inspection (general)				4.0–8.0
Wire drawing	0.87	1.0	3.0	4.0–8.0
Pipe threading	0.76	1.5	5.0	4.0–8.0
Nail making				4.0–8.0
Pickling		0.25	1.0	2.0–4.0
Tinning		1.5	5.0	4.0–8.0
Tin plate sorting and inspecting		5.0	12.0	10.0–15.0
Warehouses		1.0	2.5	2.0–4.0
Shipping		1.5	3.0	3.0–6.0
Machine shops	1.37	2.5	4.0	4.0–8.0
Power houses	1.13	2.5	6.0	4.0–8.0
Layout and fabrication (structural steel)				4.0–8.0
Foundries:				
Floor moulding and casting:				
Heavy castings	1.1	2.0	5.0	4.0–6.0
Small castings				6.0–12.0
Bench moulding and core making				8.0–12.0
Charging tumbling and cleaning				3.0–6.0

In planning a lighting installation for an iron and steel plant, adequate provision must be made for the absorption of light due to the clouded atmosphere and for rapid depreciation of reflecting surfaces. Frequent cleaning of equipment is necessary to maintain an efficient system of illumination, and but few of the plants provided for this.

The cost of good illumination is a small item in the expense of the production of steel. The author estimates that at most, it would not be more than 10c. per ton output of steel, and in the majority of instances, probably far less. He urges good lighting most of all on the score of safety, but also for facilitating supervision, increasing production, reducing spoilage and elevating the morale.

ELEVEN SOLUTIONS OF A STREET LIGHTING PROBLEM

In the summer of 1923, the Committee on Papers of the Illuminating Engineering Society, submitted a problem to a number of members interested in street lighting. The subject was one mile of thoroughfare, forming one of the main arteries of travel in and out of a city of 100,000 population. The street was 40 ft. wide from curb to curb, and 70 ft. between property lines. Lines of trolley poles extended along each side of the street.

The section was about a mile from the center of the city, built up with houses of the better grade, with a sprinkling of neighborhood stores. A plan sent to each contributor showed arrangement of intersecting and abutting streets, and a photograph indicated other conditions, such as forestation and character of trolley poles. Each contributor was asked to answer various queries and design a system of lighting for the street. Eleven solutions were received, mostly from well known engineers, six of whom were associated with the lamp and equipment business and three with the central station business.

One contributor was a consulting engineer and one was in charge of a municipal installation.

The most important features of the proposed installations are shown in a tabulation which accompanies the symposium.*

The estimate of desirable annual expenditure ranged from $2200.00 to nearly $6000.00, averaging $3748.00.

Other average values were as follows: foot candles 0.28, lumens per foot 55, size of lamps, 6300 lumens, spacing 141 ft.; height of light center 19 ft. All solutions were based on the use of gas filled tungsten lamps.

Nine engineers proposed to use series lamps, and two called for the multiple type.

Nine recommended staggering lamps, one preferred the opposite arrangement, and one the center span.

Various types of ornamental units were specified, ten contributors recommending the pendant form.

Six would utilize existing trolley poles; the remainder specified various types of additional poles. Only one solution called for overhead distribution.

The symposium is an interesting exhibit of engineering opinion as to the best method of lighting this important class of street.

*Transactions of the Illuminating Engineering Society, Vol. XVIII, No. 10, December, 1923.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Midwinter Convention Will Offer Much Timely Information

The coming Midwinter Convention in New York, February 9 to 12, will disclose some excellent new information in several technical fields. Sessions have been scheduled on electrical machinery, electrophysics, instruments and measurements, communication and transmission. In addition there will be one good paper each on storage batteries and central-station statistics. The Engineering Societies Building, 33 West 39th Street, will be convention headquarters.

The social side of the program also promises some enjoyable features. Among these is a smoker with entertainment on Monday evening, a special lecture and the presentation of the Edison Medal to this year's medalist, John W. Howell, on Wednesday evening, and on Thursday evening the meeting will close with a dinner and dance. On Wednesday afternoon those who desire may take trips to places of engineering interest. A special committee will have these trips in charge.

In accordance with the custom established during the many years when Midwinter Conventions have been held in New York, the dinner-dance will be the closing event of the Convention. It will be given as formerly at the Hotel Astor, on Thursday evening, February 12 and will prove a delightful occasion for the members and their guests in attendance. The fact that it will be held on Lincoln's Birthday should add to its popularity and provide a most enjoyable way of concluding the holiday.

A competent local committee is working to complete the details of arrangements to make the meeting of greatest possible enjoyment to those attending. The general committee is composed of the following gentlemen: L. F. Morehouse, Chairman, H. H. Barnes, Jr., W. S. Gorsuch, E. B. Meyer, L. W. W. Morrow and R. H. Tapscott. The committee on entertainment is in charge of H. H. Barnes as chairman and the chairmen of subcommittees of this committee are as follows: dinner-dance, H. A. Kidder; excursions, J. C. Parker; smoker, A. E. Waller; feature meeting, H. S. Sheppard; finance, R. H. Tapscott, and sessions, E. B. Meyer. These chairmen will have assisting them other members of their subcommittees.

Transportation Rates

Particular attention is called to the fact that reduced railroad fares have been granted on the certificate plan throughout all territory from which members are likely to attend. This plan requires each person to purchase a one-way ticket and to obtain from the selling agent a certificate, which upon presentation at the convention headquarters will entitle the passenger to one-half rate for the return trip by the same route, provided at least two hundred and fifty of the certificates are presented at the convention. Members should advise their local ticket office when purchasing their tickets of their intention to attend the A. I. E. E. convention, and ask for the certificate. Return tickets issued at such reduced fares are not good on some limited trains. Certificates must show the purchase of tickets not more than a fixed number of days prior to the date announced as the opening date of the meeting, and return tickets must be used within a certain period after the closing date. Details relative to these dates, etc., can be obtained from ticket agents. Immediately on arrival at New York certificates should be presented to the endorsing officer, H. E. Farrer, Institute Headquarters.

EVERYONE attending the Convention from any point where the regular one-way adult fare to New York is 67 cents or more is urged to apply for a certificate at the time of purchase of his ticket, *whether he intends to return by the same route or not*, as all such certificates turned in at headquarters go to make up the 250 required and help other members coming long distances to get *reduced return fares.*

PROGRAM OF MIDWINTER CONVENTION

February 9-12, New York

Monday Morning

Registration
Committee Meetings

Monday Afternoon

Session (1), under auspices of Committee on Electrical Machinery H. M. Hobart, Chairman

A New A-C. General-Purpose Motor, H. Weichsel, Wagner Electric Corporation

A-C. Commutator-Motor Design, L. W. Perkins, Westinghouse Electric & Mfg. Co.

The Effect of Full-Voltage Starting on Induction Motors, J. L. Rylander, Westinghouse Electric & Mfg. Co.

Another Form of Self-Excited Synchronous Induction Motor, Val A. Fynn, Consulting Engineer.

Monday Evening

Smoker and Entertainment.

Tuesday Morning

Session (2), under auspices of Committee on Power Transmission and Distribution, P. H. Thomas, Chairman.

The Artificial Representation of Power Systems, H. H. Spencer and H. L. Hazen, General Electric Company.

Power-System Transients, V. Bush and R. D. Booth, both of Jackson & Moreland.

Testing Impregnated-Paper-Insulated Lead-Covered Cables, Everett S. Lee, General Electric Company.

Predicting Central-Station Demands and Outputs, F. C. Ralston, Philadelphia Electric Company.

TUESDAY AFTERNOON

Session (3), under auspices of Committee on Electrical Machinery, H. M. Hobart, Chairman.

The Thermal Time Constants of Electrical Machines, A. E. Kennelly, Harvard University.

Squirrel-Cage Induction-Motor Core Losses, Thomas Spooner, Westinghouse Electric & Mfg. Company.

Complete Synchronous-Motor Characteristics, J. F. H. Douglas, E. D. Engeset and R. H. Jones, Marquette University.

Factors Affecting the Design of D-C. Motors for Locomotives, R. E. Ferris, Westinghouse Electric & Mfg. Co.

WEDNESDAY MORNING

Session (4), under auspices of Committee on Electrophysics, J. H. Morecroft, Chairman.

Study of Direct-Current Corona in Various Gases, F. W. Lee and B. Kurrelmeyer, both of Johns Hopkins University.

Effect of Repeated Voltage Application on Fibrous Insulation, F. M. Clark, General Electric Co.

Corona in Oils, A. C. Crago and J. K. Hodnette, Westinghouse Electric & Mfg. Co.

Stresses in Bus Supports During Short Circuits, O. R. Schurig and M. F. Sayre, General Electric Company.

WEDNESDAY EVENING

Presentation of Edison Medal.

Lecture by prominent speaker on subject of wide interest.

THURSDAY MORNING

Session (5), under auspices of Committee on Instruments and Measurements, A. E. Knowlton, Chairman.

Electrical Measurements of Physical Values, Perry A. Borden, Hydroelectric Power Commission of Ontario.

Use of the Oscillograph to Measure Mechanical Phenomena, Harvey L. Curtis, Bureau of Standards.

Temperature Errors in Induction Watthour Meters, I. F. Kinnard and H. J. Faus, General Electric Company.

Storage-Battery Electrolytes, G. W. Vinal, Bureau of Standards.

THURSDAY AFTERNOON

Session (6), under auspices of Committee on Communication, O. B. Blackwell, Chairman.

The Theory of Probability and Some Applications to Engineering Problems, E. C. Molina, American Tel. & Tel. Co.

The Design of Distortionless Power Amplifiers, E. W. Kellogg, General Electric Company.

Metallic Polar-Duplex Telegraph System for Long Small-Gauge Cables, J. H. Bell, Western Electric Company and R. B. Shanck and D. E. Branson, both of American Telephone & Telegraph Co.

Voice-Frequency Carrier Telegraph Systems for Cables, B. P. Hamilton and H. Nyquist, both of American Telephone & Telegraph Co. and M. B. Long and W. A. Phelps, both of Western Electric Company.

Polarized Telegraph Relays, J. R. Fry, Western Electric Company and L. A. Gardner, American Telephone & Telegraph Co.

THURSDAY EVENING

Dinner-Dance at Hotel Astor.

Washington, D. C. to Have Regional Meeting in January

The second regional convention of the Institute has been scheduled to be held in Washington, D. C., on January 23 and 24, at the Washington Hotel. This meeting will be conducted under the direction of Geographical District No. 2 and will be especially sponsored by the members in the eastern part of that District.

A two-day meeting is planned, Friday and Saturday; the papers to be presented will be of high grade and of varied interest. One especially good feature of the meeting is that there will be ample time for presentation and discussion of papers. It is planned to have three technical sessions, Friday morning, Friday afternoon and Saturday morning. At each session there will be only two papers so that plenty of time will be allowed each paper.

THE TECHNICAL SESSIONS

On Friday morning a discussion of the advantages and means of raising low power factor will be given by L. W. W. Morrow, Associate Editor, *Electrical World*. There will be a paper on the use of frequency changers for interconnection of power systems by H. R. Woodrow, Brooklyn Edison Company. A discussion on protection of lines against lightning will be given on Friday afternoon by Joseph Slepian, Westinghouse Electric and Manufacturing Company. Another paper will have as its subject problems of transmission systems.

On Saturday morning it is planned to have a paper on features of electrical machine design by an eminent authority. Another paper will be on some of the latest developments in studies of electrophysics.

A dinner will be held on Friday evening at the Washington Hotel and on this occasion an address will be made by a man of national prominence. Those who plan to attend the dinner should notify Edward Kerschner, Wilkins Building, Washington, D. C.

Arrangements are planned to allow visitors to see the many interesting sights of Washington, both engineering and otherwise, and these alone will make attendance at the meeting worth while to many.

The meeting will be held under the direction of the Executive Committee of the District consisting of Vice-President W. F. James and the Chairman and Secretaries of all Sections in the District.

The local committee in charge of arrangements consists of J. H. Ferry, Chairman of the Washington Section, and the following subcommittee members: Program—A. R. Cheyney, Chairman, E. C. Crittenden, J. F. Meyer, L. D. Bliss, T. J. McKavanaugh, N. B. Ames and A. Robinson; Hotels and Hall—Edward Kerschner, Chairman, R. H. Dalgleish and Roland Whitehurst; Finance and Budget—A. E. F. Horn, Chairman and F. R. Mueller; Transportation—T. F. Flotz, Chairman; Reception and Entertainment—J. H. Finney, Chairman; Trips and Inspections—L. M. Evans, Chairman, H. B. Stabler and R. H. Hamilton; Publicity—R. H. Parrott, Chairman.

All visitors should make their own reservations by direct communication with the hotels. The names and rates of hotels in Washington are given in the following table.

HOTEL RATES—PER DAY

	Single Room (without bath)	Single Room (with bath)	Double Room	Double Room (with bath)
Washington Hotel, 15th & Penna. Ave., N. W.		$5.00 to $7.00		$8.00 to $12.00
Willard Hotel 14th & Penn. Ave., N. W.	$3.00 and up.	$5.00 and up.		$8.00 and up.
Raleigh Hotel, 12th & Penn. Ave., N. W.	$3.00—$5.00	$4.00 to $6.00	$4.00 to $6.00	$5.00 to $10.00
Roosevelt Hotel 16th & V Streets, N W.		$4.00 and up		$5.00 and up.

Mine, Mill and Marine Applications Features of Spring Meeting

The Spring Convention which will be held in St. Louis, April 13-17, will offer the latest information on a large variety of subjects. Notable among these will be new power plants, marine installations, automatic stations, communication, in-

dustrial applications in cement and paper mills and in mines. Stability of high-voltage transmission will be covered as well as several other topics. St. Louis is of particular interest because it is a center of industrial enterprises and a convention there should draw many engineers connected with industrial applications.

A feature meeting of unusual interest with two prominent speakers has been planned for one evening of the week. The local committee which is handling arrangements is actively engaged in perfecting plans to make the meeting a noteworthy success. This committee as appointed by President Osgood is composed of B. D. Hull, Chairman, Edward Bennett, H. E. Bussey, J. M. Chandlee, H. W. Eales, J. Harrison, Chris. H. Kraft, L. W. W. Morrow, C. P. Potter, W. L. Rose and Herbert S. Sands.

Future Section Meetings

Boston

Frequency Control of Speech and Music, by Dr. Harvey Fletcher. In addition to many of the affiliated societies the following societies will be represented at this meeting: Institute of Radio Engineers, Harvard Engineering Society, Local Telephone Engineering Society, American Physical Society, Mass. Medical Society, Triological Society, N. E. Otological Society, N. E. Conservatory of Music, N. E. Music Teachers Association, and the Boston Symphony Orchestra. The meeting will be held in Jordan Hall, January 24.

Erie

Talk by James Burke, Burke Electric Company. January 20.

Manufacture of Railway Motors, by Don F. Smith, General Electric Co., February 17.

Fort Wayne

Annual Dance. Packard Music Hall. January 22.

Supervisory System for Automatic Stations, by Chester Lichtenberg, General Electric Co. This will be illustrated by movies. To be held at G. E. Club Rooms, Building 16-2, 8.00 P. M. February 19.

New York

The Applications of X-Rays. A talk on the very extensive applications of X-Rays will be given before the New York Section of the Institute in the Engineering Societies Bldg., on the evening of Wednesday, January 14, 1925 by Dr. W. P. Davey, Experimental Staff, Research Laboratory, General Electric Company, Schenectady, N. Y. Dr. Davey will tell not only of the use of the X-Ray for studying defects in metals and its more universally known application to human analysis, but he will also show how this discovery is serving for disclosing ultra-microscopic structure of matter, even to the point of atomic structure and its very nuclei. Preceding Dr. Davey's talk Dr. W. R. Whitney, Director of the Research Laboratory, will give a short address on *Industrial Research.* All interested are invited to be present as the guests of the N. Y. Section.

Seattle

Engineering and Economic Features of the Proposed Columbia Basin Development, by Major Joseph Jacobs. January 21.

Recent Developments in Propulsion, by F. K. Kirsten. February 18.

Vancouver

Talk by J. G. Lister. January 9.

Alouette Power Developments, by E. E. Carpenter. February 6.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, December 5, 1924.

There were present: President Farley Osgood, Newark, N. J.—Vice-Presidents William F. James, Philadelphia; Harold B. Smith, Worcester; L. F. Morehouse, New York; H. W. Eales, St. Louis—Managers A. G. Pierce, Pittsburgh; Harlan A. Pratt, Hoboken, N. J.; H. P. Charlesworth, New York; H. M. Hobart, E. B. Merriam, Schenectady; G. L. Knight, Brooklyn, N. Y.; John B. Whitehead, Baltimore—Treasurer George A. Hamiliton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

Reports were presented of meetings of the Board of Examiners held October 27 and December 1, 1924; and upon the recommendation of the Board of Examiners the following actions were taken upon pending applications: 476 Students were ordered enrolled; 102 applicants were elected to the grade of Associate; 3 applicants were elected to the grade of Member; 5 applicants were transferred to the grade of Member.

The Board ratified the approval by the Finance Committee for payment of monthly bills as follows: October, $32,530.02; November, $25,269.52.

A list of members in arrears for dues for the year ending May 1, 1924, consisting of one (1) Fellow, 31 Members, and 699 Associates, was presented; and the Secretary was authorized to remove from the membership list on December 31, 1924, the names of all those whose dues remain unpaid at that time and who have not indicated a desire to continue membership, requesting an extension of time for payment of the dues.

A report was presented of the Special Committee on Election Procedure, appointed by the Board in February 1924 to study and make recommendations regarding the Institute's election procedure, and was referred to a Committee on Revision of the Constitution, which the President was authorized to appoint.

The Committee on Coordination of Institute Acitvities submitted a report of matters that had been considered, covering the following subjects: Qualifications for the grade of Associate, expulsion of members, increase in entrance fees, exemption from payment of dues of members of thirty-five years' standing, Life Membership—recommendation that it be placed upon an actuarial basis instead of the payment of a flat sum, schedule of conventions for 1925, Geographical District prizes, Edison Medal presentation. The report was received and the various recommendations were either approved or referred to the proper committees for further consideration.

The following proposed conventions during 1925, as recommended by the Meetings and Papers and the Coordination committees, were approved by the Directors:

- Midwinter Convention, New York, February 9–12.
- Spring Convention, St. Louis, April 13–17.
- Annual Convention, Saratoga Springs, June 22–26
- Pacific Coast Convention, place and date to be decided (probably September or October).
- Regional Conventions, District No. 2, Washington, January 23–24; Cleveland, May 22–23.
- Regional Convention, District No. 1, Swampscott, Mass., May 7-9.

The Board voted that the following rules be established in regard to the Geographical District prizes: that in each instance the award shall cover a calendar year, rather than the Institute administrative year; and that to be eligible for a Geographical District prize, a paper must be presented at a Section or a District meeting, by a member in the same District.

The Board voted that the Edison Medal for 1924 be presented to the medalist (John White Howell) during the Midwinter Convention, in February.

Upon the recommendation of the Committee on Student

Branches, the Board authorized the organization of a Student Branch of the Institute at New York University, New York City.

Approval was given to minor revisions to the Institute's Standards on Industrial Control Apparatus, submitted by the Standards Committee.

Various appointments of Institute representatives were referred to the President with power, who later appointed the following: Mr. Bancroft Gherardi reappointed on Board of Trustees of United Engineering Society, for term of three years beginning in January 1925; Mr. E. B. Craft reappointed on the Library Board, United Engineering Society, for term of four years beginning January 1, 1925; Mr. Gano Dunn on Engineering Foundation Board, for term of three years beginning in February 1925; Mr. H. S. Osborne reappointed as representative on American Engineering Standards Committee for term of three years beginning January 1, 1925, and Mr. L. T. Robinson as alternate on the A. E. S. C. for year 1925; Mr. J. F. Clinton as representative, and Mr. G. A. Pierce as alternate, on American Marine Standards Committee.

A report was presented from Dr. A. E. Kennelly, the Institute's delegate to the Third National Radio Conference held in Washington, October 6–10, 1924. The report was received with an expression of appreciation of Dr. Kennelly's services, and copies were ordered to be sent to the members of the Board.

A communication was presented from Mr. W. E. Wickenden, Director of Investigation, Society for the Promotion of Engineering Education, requesting the cooperation of the Institute in the study of engineering education being conducted by the Society under a grant from the Carnegie Corporation, and transmitting certain suggestions for the Institute's contribution to this study. The matter was referred to the Committee on Education.

Complying with a request to contribute a file of Institute publications to the Library of the Masaryk Academy, at Prague, Czechoslovakia, it was voted that a set of the A. I. E. E. TRANSACTIONS be donated to this library.

An invitation to send a representative to an Engineering Conference to be held in Panama, in February 1925, was referred to the chairman of the Panama Section of the Institute.

An invitation from Secretary Hoover of the Department of Commerce to send a delegate to a National Conference on Street and Highway Safety, Washington, December 15-17, 1924, was accepted, and Mr. John H. Finney, of Washington, was appointed as the Institute's representative at this conference.

Consideration was given to a cummunication from the Secretary General of the International Conference on Large High Tension Electric Systems, Paris, June 1925, announcing the conference and suggesting that a national committee be organized in this country to cooperate in the conference. As cooperation in previous conferences on this subject was handled by the United States National Committee of the International Electrotechnical Commission, the matter was referred to that body.

The date of the next meeting of the Board of Directors was tentatively set as January 21, 1925.

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

Nomination and Election of Institute Officers for 1925-1926

As provided in Section 19 of the Institute By-Laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1925, by the petition or by the separate endorsement in writing, of not less than twenty-five members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1925. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available. A member is not limited in the number of candidates he may endorse in this manner.

The officers to be elected are: A President and a Treasurer for the term of one year each, five Vice-Presidents for the term of two years each (one from each of the even numbered geographical districts), and three Managers for the term of four years each.

The five even numbered districts from which Vice-Presidents are to be chosen at the May 1925 election are as follows:

2. MIDDLE EASTERN: Deleware, District of Columbia, Maryland, New Jersey (exclusive of N. Y. Section territory), Ohio, Pennsylvania, West Virginia.

4. SOUTHERN: Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia.

6. NORTH CENTRAL: Colorado, Iowa, Minnesota, Nebraska, North Dakota, South Dakota, Wyoming.

8. PACIFIC: Arizona, California, Nevada, Hawaii, Phillippines.

10. Canada.

According to the revised Constitution while one Vice-President must be elected from each of the five even numbered districts, this does not debar members in one district, if they so wish, from nominating and voting for a candidate in another district. When the votes are counted the candidate for Vice-President having the largest vote in each district will be elected to that particular office for that district, irrespective of the fact that he may have polled a smaller number of votes than a candidate standing second in another district.

For the information of members the full text of revised sections of the Constitution and By-Laws applying to Officers, nominations, elections, etc., are printed below:

CONSTITUTION

SEC. 23. The officers of the INSTITUTE shall be a President, one Vice-President from each geographical district as defined in the By-Laws, twelve Managers, a Secretary and a Treasurer.

SEC. 24. The President, the Secretary and the Treasurer shall hold office for one year, the Vice-Presidents for two years and the Managers for four years. The President and Managers shall not be eligible for immediate re-election to the same office. No Vice-President or Manager who has served continuously in one or more offices, and whose combined terms shall have aggregated six years or more shall be eligible for immediate election to the office of Manager or Vice-President. At each Annual Meeting the President, the requisite number of Vice-Presidents to fill vacancies caused by expiration of terms, three Managers and the Treasurer shall be elected by the membership, and their terms of office shall commence on the first of August next succeeding their election. . . . .

SEC. 24A. At the election of Vice-Presidents held in 1921 there shall be elected one Vice-President from each geographical district, those from the odd-numbered districts to serve for one year each, and those from the even-numbered districts two years each. All Vice-Presidents elected thereafter shall serve for two years each. In the event of a change in the geographical districts, the Vice-Presidents then in office shall complete their terms. In case of revisions of the geographical districts, the Board of Directors shall have the power to elect a Vice-President from each district not represented to serve until the next election covering these districts.

BY-LAWS

SEC. 19. In addition to the names of the incumbents of office the Secretary shall publish on the form showing offices to be filled at the ensuing annual election in May provided for in Article VI, of the Constitution, the names, as candidates for nomination, of such members of the Institute as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than twenty-five members, received by the Secretary of the Institute in writing by January twenty-fifth of each year; provided, however, that any candidate proposed for nomination by petition may withdraw his name by written communication to the Secretary, and any name so withdrawn prior to the printing of the form shall not be published.

The names of such candidates for nomination shall be grouped alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the December and January issue of each years' JOURNAL and shall be reproduced on the form above referred to.

SEC. 21. There shall be ten geographical districts grouped as follows: (For the balance of this Section describing districts see By-laws and map.)

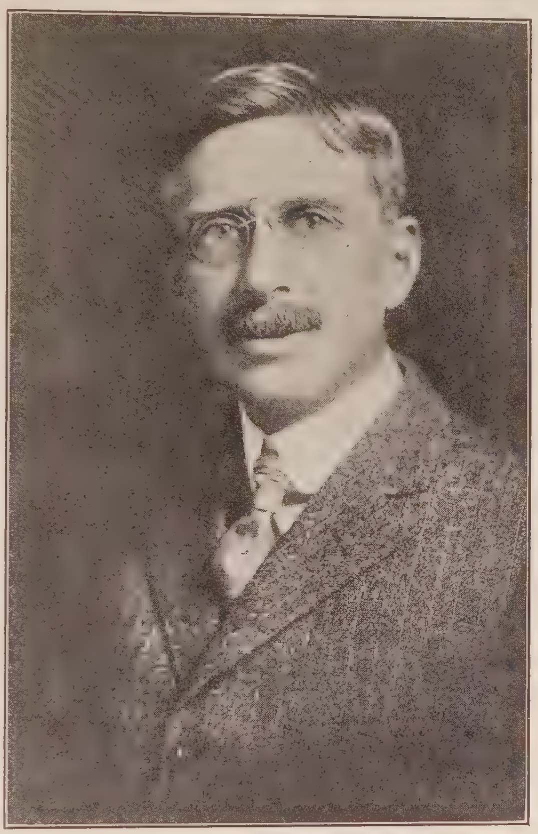
SEC. 21A. Should the territory of any Institute Section lie in more than one geographical district as defined above, then the entire territory of said Section shall be considered as belonging to the geographical district in which the headquarters of the Section are located.

Edison Medal Awarded to John White Howell

The Edison Medal for the year 1924 has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to John White Howell of Newark, New Jersey, "for his contributions toward the development of the incandescent lamp."

The Edison Medal was founded by the Edison Medal Association, composed of associates and friends of Mr. Thomas A. Edison, and is awarded annually by a committee consisting of twenty-four members of the American Institute of Electrical Engineers for "meritorious achievement in electrical science, electrical engineering, or the electrical arts."

The following men have been recipients of the medal: Elihu Thomson, 1909; Frank J. Sprague, 1910; George Westinghouse, 1911; William Stanley, 1912; Charles F. Brush, 1913; Alexander Graham Bell, 1914; Nikola Tesla, 1916; John J. Carty, 1917; Benjamin G. Lamme, 1918; W. L. R. Emmet, 1919; Michael I. Pupin, 1920; Cummings C. Chesney, 1921; Robert A. Millikan, 1922; John W. Lieb, 1923.



JOHN WHITE HOWELL

Mr. Howell, engineer and inventor, was born in New Brunswick, New Jersey, on December 22, 1857. After leaving school he went to the College of the City of New York, where he took an academic course for a year and a half. He then went to Rutgers, where he studied engineering for a year, and finally to Stevens Institute where he finished a special engineering course, in 1881. Later, in 1898, he was given the honorary degree of Electrical Engineer by Stevens Institute.

On July 6, 1881, he entered the employ of the Edison Lamp Company at Menlo Park, New Jersey. At that time the lamp industry was in its infancy, without machinery and without methods. For several years the technical work at the factory was supervised by Mr. Edison. Then he gradually withdrew, and eventually left the work in Mr. Howell's charge. In the forty-three years that have passed since 1881, Mr. Howell has remained with the Edison Lamp Works, and his numerous important inventions and many written contributions have been vitally constructive factors in the improvement and enlargement of incandescent lamp production.

Two of his earliest achievements were his development of a successful, portable voltmeter and a Wheatstone Bridge type of potential indicator, which compensated for temperature, and which was widely used in central stations and electric light plants. At a later date, Mr. Howell originated the comparative indicator, a novel system which gave the voltage at each feeder end by comparison with one standard indicator.

In 1886 he determined for the first time the relation between the life and the candle-power of incandescent lamps, which applies to all forms of incandescent lamps made since that time. The next year he introduced a carbonaceous paste clamp which greatly decreased clamping and filament costs and greatly increased the quality of the lamp. When, in 1890, he was appointed Technical Advisor to Manager of Works, he made certain changes in the exhaust which increased the speed of exhaust and improved the quality of the lamp.

In 1892, the year the Edison Lamp Works became part of the General Electric Company, Mr. Howell was appointed Engineer and Assistant Manager of the Lamp Works. His experimental investigations continued. He organized the Edison Lamp Works Engineering Department. He improved the Thomson-Houston method of treating carbon filaments and developed a treating machine which entirely revolutionized the most important process in lamp making. He introduced the squirted cellulose filament which reduced the number of operators in the filament department from 350 to 12. As an inventor and an engineer and a manager, Mr. Howell was ever a moving force in the direction and development of the then new industry of lamp manufacture. His influence and his many technical achievements can not easily be catalogued. His patents, numbering forty in all, cover a wide variety of inventions of parts, processes and machinery used in the evolution of the electric lamp.

He resigned as Assistant Manager in 1895, as the engineering duties were more congenial and demanded all of his time. In that same year he investigated, reported favorably upon, and introduced the Malignani methods of exhaust, whereby production was enormously increased. With Mr. W. R. Burrows he designed and patented the first stem-making machine, which revolutionized that process and which is still in use today. He tested and investigated various filament inventions, and assisted Dr. W. R. Whitney in the development of the metallized filaments. In 1906 much of his time was spent in Europe for the purpose of studying the invention of the Tungsten lamp and for the acquiring of their American rights.

Today he is the most distinguished of our pioneer incandescent lamp engineers. In the evolution and development of that lamp he has rendered invaluable services. For forty-three years he has carried on an enormous amount of research work which has given the incandescent lamp its present universal usefulness. The general public, as well as the entire electrical industry, have enjoyed the results of his labors; and, as the lighting branch was for many years the foundation, the parent, of the light and power industry as we know it today, it is certain that Mr. Howell has played a most important and distinguished part in the scientific progress of his day.

Mr. Howell is a Fellow of the American Institute of Electrical Engineers; member of the American Society of Mechanical Engineers, National Electric Light Association of Edison Illuminating Companies, Illuminating Engineering Society, Franklin Institute and past President of the Edison Pioneers.

The medal will be presented to Mr. Howell at an evening session during the Midwinter Convention, New York, February 9–12, 1925.

Revision of A. I. E. E. Constitution

At the December meeting of the Board of Directors, the Special Committee on Election Procedure, appointed in the spring of 1924, to study the election procedure of the Institute,

submitted a report recommending some changes in the method of election, whereby but one ballot would be sent out to the membership instead of, as in the past, a nomination ballot and later an election ballot. It is also proposed to institute a Nominating Committee, composed of one representative from each of the ten Geographical Districts of the Institute and five additional members, selected by the Board of Directors, making a total of fifteen members—who shall prepare an official nominees ticket after giving consideration to all suggestions that may be received from the membership. Provision will also be made for other candidates upon nomination by groups of members.

This report was referred for consideration to a Committee on Revision of the Constitution which the President was authorized to appoint. In accordance with this action, President Osgood later appointed Messrs. L. F. Morehouse (Chairman), G. L. Knight, W. I. Slichter, Harold B. Smith, and W. K. Vanderpoel, as members of the constitutional revision committee.

The Board also referred to this committee, for later report to the Board of Directors, consideration of the following matters: qualifications for the grade of Associate, expulsion of members, suggested increase in entrance fees, exemption from the payment of dues of members of thirty-five years' standing, Life Membership—shall it be placed on an actuarial basis instead of a flat sum?

The Committee on Revision of the Constitution has authority to consider all of the above matters and any others that they may initiate or that may be referred to them by the membership. Any member who desires to make a suggestion or recommendation regarding a revision of the constitution is therefore urged to communicate as promptly as possible, with the chairman of the committee, who may be addressed at Institute headquarters, as it will be necessary for the committee to make its recommendations to the Board of Directors at the January meeting, which has been tentatively set for January 21.

The A. I. E. E. and It's Work

By L. W. W. Morrow
Member, A. I. E. E.,
Chairman A. I. E. E. Meetings & Papers Committee

What has caused the growth of a professional engineering organization from a membership of about twelve hundred in 1901 to over sixteen thousand in 1924? What real service does the American Institute of Electrical Engineers render to the profession, to society and to its membership? What does it do and how is it organized to accomplish results?

These are natural and inevitable questions that must be asked and answered to assure the members their professional society is worthy of fealty and support. The answers are contained in the statement that the Institute is the best agency for recording and securing electrical engineering developments and for improving the standing of individual engineers.

The real reason for the development of this great professional engineering society lies deep in economics and pyschology and is linked with the evolution of society. The Institute is one of the many agencies called forth by the necessities of modern civilization in order to organize and group individual efforts and individual knowledge for securing effective results.

Scientists have delved into the past in an attempt to determine how much the intelligence of modern man has developed since the age of prehistoric man. The results are totally negative for surely Confucius, Buddha, Plato, Caesar, and other ancients exhibited an intelligence as individuals comparable to that found in modern beings. But whatever may be said of native intellectual ability, modern man has developed a technique and recorded a body of facts which give him a mastery over his environment infinitely superior to that possessed by primitive man. Thus his intelligence enjoys enormous advantages and in science particularly there seems to be literally no limit to the mastery which he can attain over the forces of nature and consequently no limit to the alterations he may be able to bring about for the enrichment of civilization.

Brain action strengthened by knowledge and technique is used to harness the forces of nature and every such realized thought is an added increment to the knowledge, culture or apparatus of civilization. The material increments such as the motor, locomotive and turbine are joined to mental, social and cultural contributions equally valuable to make the modern world, for civilization is a composite resulting from the product and the contact of innumerable increments. These increments are produced by the application of both individual and group efforts and of the two, organized group action is the more potent and accomodates itself best to modern conditions. The Institute is the available agency for securing and coordinating individual talents to focus them on electrical engineering development.

Now-a-days, advancement does not result from experimental accidents, mental fumblings or individual achievements; it usually comes to fruition as the result of a long line of scientific experimenters and thinkers the last of whom breaks the top crust so the sprout can reach the light. With organization it becomes possible to parallel and coordinate the efforts of individual workers and thus speed the discovery of new things useful to the world. This is the fundamental conception of organized engineering today which contrasts vividly with the conditions existing in the past. In the speculative era of human history contributions were made by individuals through the play of genius: Plato, Aristotle, Pythagoras and other geniuses worked as individuals outward into nature and possessed little knowledge and technique. A little later the scientific era began and fact began, to replace speculation. Geniuses such as Galileo, Descartes and Bacon began to experiment and to record observed facts regarding the laws of nature and still later Watt, Ohm, Faraday, Maxwell, Newton, Kelvin and many others applied and coordinated recorded knowledge to state the laws of nature. And here the age of the genius passed in large degree, for the engineer arrived to harness science and economics together for doing the work of the world. Group effort and planned developments replaced individual effort and haphazard experimentation so that civil progress went on apace and business and government were made possible on an unlimited scale.

Genius exists today but is too insufficient to the secure advancements quickly and fully. Engineers are fighting on the battlefront of civilization and each time a genius charges ahead into unknown territory others must rush forward in support to consolidate the position. In other cases, a planned and massed attack is an improvement on sporadic and individual forays into enemy territory. Engineering advances are nearly always made on the basis of careful plans prepared beforehand, using as weapons, the recorded knowledge and acquired technique of years of experience in scientific warfare.

The Institute makes possible these achievements for electrical engineers. It has a mass of specialized knowledge available to all members and added too by all members; it has an educational process which develops its members and magnifies their power of accomplishment; it has standards of conduct to improve ethical conditions; it has a recognized status which permits it to be useful in national affairs and, finally, it has a common interest core of electricity which makes its members cling together in fealty to their science.

Engineers are in reality idealists, for the pursuit of science is the seeking of a closer acquaintance with the infinite which has produced the romance of nature. This pursuit has led to the inevitable conclusion that the energy element in orb-filled space is electricity. There is nothing in the whole series of universal phenomena which may not be accounted for by the agency of the forces loosed by electricity and with its coming the horologe of time struck and an older age passed away. Through a knowledge of electricity the realm of the universe is taken from the dominion of marvel and placed under the rule of known science.

Address before the Lehigh Valley Section, Pottsville, Pa., November 21, 1924.

This intangible force produced the crowning phenomena of modern times and is the most potent agent for improving the status of mankind. Through the application of this great force the electrical engineer has been raised to almost omnipotent control of human destiny and the thrilling idealism of this thought reaches its highest consummation in the Institute with it's ideals of service and the dedication of it's ideals to advancing the art.

Electrical engineers join the Institute because they desire to be of service and wish to make their services effective. They join the Institute to obtain self expression and to tell of their work as well as to consult with fellow workers. They join the Institute because they have a conscious recognition of their social and prefessional duties as citizens and engineers. It is the outlet for their knowledge and for their desire to serve; it multiplies their power to do and to be. Each member is better able to orient his service to his profession, to add to his expertness and to contribute to the work of other engineers. Each member comes in contact with ideals and ideas which nurture his individual gifts and coordinates them to produce the radio, airplane or other miracle of attainment.

Detail of Institute Organization

These fundamental considerations explain the existance and the growth of the American Institute of Electrical Engineers but specific details are needed to show the work the Institute is doing to secure the greatest possible achievement and a proper measure of its work is by weighing its accomplishments with the noble expressions written into the constitution by its founders who stated "the object of the Institute is the advancement of the theory and practise of electrical engineering and of the allied arts and sciences, and the maintenance of a high professional standing among its members and the development of the individual engineer."

A study of Institute's history shows these broad objectives have been kept ever in view by Institute officers and the past records are replete with evidence that these expressions of faith have been ever in mind. In every phase of electrical engineering the Institute has carried the flag of the profession and has kept its honor unsullied by selfish or commercial influences. From the beginning it has stood as the symbol for unhampered professional development. It has kept faith with its founders.

Through years the Institute has developed and expanded and the organization of today is as follows:

- President—one-year term
- Ten Vice-Presidents, one from each of the ten geographical districts—two-year terms
- Twelve Managers—four-year terms
- Secretary—one-year term
- Treasurer—one-year term
- Ten Geographical Districts
- Forty-seven sections
- Seventy-six Branches
- Thirty-one Committees
- Eighty-five Representatives on fourteen National and International Committees
- Ten Honorary Secretaries in Foreign Countries.

The official executive body consists of the Board of Directors and this is composed of the President, two Junior Past-Presidents, the Vice-Presidents, the Managers and the Treasurer. Through committee workers, geographical districts, Sections and Branches the Institute is decentralized to a remarkable degree and is made effective and useful to the art and to individual members.

Major Divisions of Activity

Probably the greatest work of the Institute is the body of electrical knowledge it produces, scrutinizes and records each year. This vast body of knowledge is of incalculable value to the art and is made possible by careful and thoughtful work by many men. Any member of the Institute is free to write and submit a paper on any topic within the scope of Institute activities and a conservative estimate is that about twelve hundred papers were written and presented to the Institute at its meetings during the past year. These papers covered all phases of the art and were presented at branch meetings, section meetings, regional meetings and national conventions. They were heard and discussed by about ninety thousand engineers. And at the end of the year they were sifted and scrutinized by competent men in order that those of permanent value might be recorded in the TRANSACTIONS. In addition, many more are printed in the monthly JOURNAL and thus made available quickly to electrical engineers in all parts of the world. This great body of knowledge is an asset of immeasurable value to the electrical engineering profession, and the Institute is the only agency that makes it possible to record the complete details of technical advances in the art.

The educational work of the Institute is another great task done well. In the compilation, presentation and discussion of papers at the many meetings of the Institute and its subdivisions, engineers are able to learn and to advance in their professional standing. They meet their fellow-workers on a professional and social plane which gives great opportunity for personal advancement and education. In Committee work also they find a fertile field for educational gains and the educational by-products of Institute membership can be found in every division of activity. It is the one place where every member and speaker can talk or listen as a professional electrical engineer unhampered by commercial or other considerations.

Progress in the electrical art is sometimes hampered because past accomplishments are allowed to intervene with developments. Standards serve to fix things done so that new developments can occur more readily, and in the fixing of electrical standards the Institute has long held the lead in the electrical industry. A small executive committee and a large group of working committees on specific standards, labor continually in the Institute and produces electrical standards which are received as authoritative. This work alone warrants the existance of the society and the future promises still more activity in standardization.

But not content with these tasks the Institute lends a helping hand to those seeking technical advancement in the several fields of endeavor. Sixteen technical committees labor continuously on the problems ahead and attack them with the aid of the best professional talent in America; they produce papers and reports which aid in developments; they serve as the court of last resort on technical questions and coordinate the technical work of the profession. Adequate recognition of the work of these committees has never been had, for the members have been too busy to seek the light of public applause. They are of great service in developing the art of electrical engineering and deserve the wholehearted support of the profession.

Yet there are many other things the Institute does which give service. It has come to be recognized as the mouthpiece of the electrical profession and it has accredited representatives on the National Research Council, the American Engineering Council, the International Electrotechnical Commission and a host of other committees and agencies which speak for all engineers on technical, social, political or economic questions of vital importance to civilization. The Institute confers honors and prizes to stimulate advances in the art and has built a splendid record for national service in every legitimate phase of electrical engineering activity.

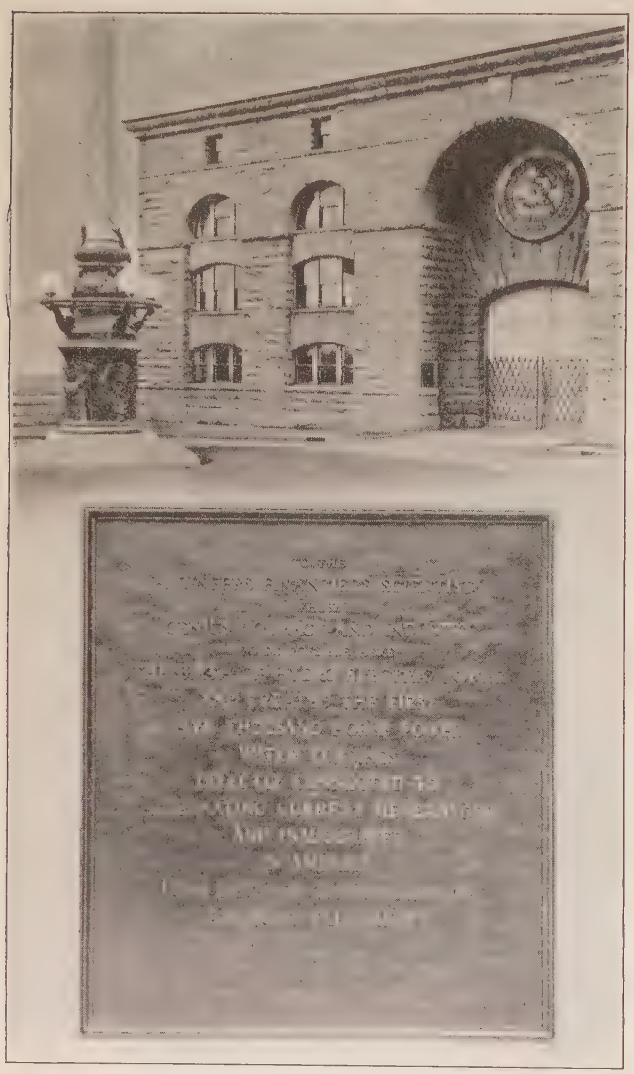
Through the years passed the creditable work of the Institute has hallowed it so that every member takes pride in his affiliation. It has come to symbolize the team play idea in electrical engineering and has effectively secured group action so that future advances will come more quickly. Every electrical engineer belongs in its ranks to give and to receive, for the years

to come glow with opportunities which can be grasped and used effectively through the application of group efforts in the American Institute of Electrical Engineers.

Niagara Falls Tablet Unveiled

There will be unveiled at Niagara Falls at noon January 3, a tablet of enduring bronze to mark the location of the first large-scale development of Niagara power.

In this dignified and lasting manner The Niagara Falls Power Company expresses its appreciation of the engineers, officers and scientists whose genius, courage and industry brought into being



A Bronze Tablet Erected in 1924 on the Left Wall of the Portal Entrance to Power-House No. 1, as an Enduring Tribute to the Pioneers of The Niagara Falls Power Company of 1886

a service destined in ever increasing fashion to benefit millions of people.

It is fitting that this tablet should have been erected at the portal entrance to Power House Number One, wherein were installed thirty years ago the world's first 5000 horse power water turbines directly connected to alternating current generators. Equally appropriate is the time of unveiling this tribute to the Niagara power pioneers, for it marks the completion of the latest Niagara power project on the American side of the river. In this new power house again we find the world's largest turbines—three gigantean water wheels, each capable of delivering in excess of 70,000 horse power.

Thirty years ago the engineering and scientific world wondered where and how the fifteen thousand available horse power of Niagara's energy could ever be utilized. Today the American generating system at Niagara constitutes a pool of power from which Western and Central New York State draws nearly a half million continuous horse power of electrical energy to lighten labor in the home, the shop and the factory.

Truly has this industry earned the right to its slogan—"The Greatest Good to the Greatest Number."

Carnot Centenary Commemoration

In commemoration of the first ennunciation one hundred years ago by Nicolas Leonard Sadi Carnot, scientist-engineer, of the principles of the thermodynamic cycle, a meeting under the joint auspices of the four national engineering societies, the American Physical Society, the American Chemical Society, Columbia and New York Universities, Stevens Institute, College of City of New York, Polytechnic Institute of Brooklyn, Pratt Institute and Cooper Union, was held on the evening of Thursday, December 4, 1924, in the auditorium of the Engineering Societies Building, New York City.

Dr. Wm. F. Durand, Stanford University, President, A. S. M., E. presided and addresses were made by Dr. M. I. Pupin, Professor of Electro-mechanics, Columbia University; Dr. W. L. R. Emmet, Consulting Engineer, General Electric Co.; M. Paul Gripon, Naval Attache French Embassy, personal representative of Ambassador Jusserand, Professor Charles Fabry, University of Paris. In opening the meeting the Chairman spoke in part as follows:

"If we could gain some faint concept of the debt which the present age owes to SADI CARNOT and to the principle which he first enunciated in full and complete form, let us ask of ourselves the Question:

To what extent do the elements of our daily life depend upon the utilization of power? To what extent are we thus dependent for food to eat, for clothing to wear, for shelter from the elements —in short for all our material possessions:—again for facilities of travel and the interchange of commodities over the earth's surface; for facilities of communication with our fellows by mail, by telegraph, by telephone, by radio—and in short, for the distinctive elements which go to make up the material content of our present day civilization? To what extent are we dependent for all these upon the utilization of power—the useful application of the energies of nature to the requirements of our civilization?

And, then, with some faint image of the extent of this dependence forming in the mind, let us ask a second question:—What part of this dependence traces back to *heat* as its source?—heat from coal, from gas, from petroleum oil and its derivative products; The answer to this query forms, even as the question is asked and we recognize the fact that in overwheming proportion the power required to produce and maintain the material content of our present day civilization traces back for its source to that great undifferentiated ocean of energy embodied in molecular agitation, and which we know under the name of heat.

The measure then of this dependence on power drawn from heat as a source is the measure of the obligation which we owe to do honor to the name of SADI CARNOT."

Changes in General Electric Company

The General Electric Company have made some active changes in their force, and the resignation of G. E. Emmons, as vice-president in charge of manufacturing and chairman of the manufacturing committee has led to the appointment of Francis C. Pratt to take his place. Mr. Pratt's new title will be vice-president in charge of engineering and manufacturing. He will have has his assistant vice-president H. F. T. Erben, with E. W. Allen as engineering assistant.

Mr. Pratt was born in Hartford, Conn., January 19, 1867, was graduated with the degree of Ph.D. from the Sheffield School, Yale University, in 1888, and in 1890 entered the employ of the Pratt & Whitney Company, Hartford. He was advanced to the vice-presidency, but in 1906 left them to affiliate himself with the General Electric Company, as assistant to E. W. Rice, Jr. His appointment as assistant to the President took place in 1912 and in 1919 he was again elevated to vice-presidency in charge of engineering.

Mr. Erben, the new assistant vice-president, has been identified with the General Electric Company ever since its early Schenectady days. In 1887, Mr. Erben was with the Edison Machine Works, but became designing engineer of the direct current department of the General Electric shortly after its formation in 1892. In 1914, Mr. Erben was made engineer of the Schenectady Works and in 1916 was appointed assistant manager. Following Mr. Emmons' retirement as works manager in 1920, Mr. Erben assumed full charge as manager, a position which he held until 1923, when C. E. Eveleth was made works manager.

Mr. Allen, manager of the engineering department, was born in Buchanan, Va., in 1880, was graduated from the Virginia Polytechnic Institute in 1900 with the degree of B. S. in electrical engineering. He first entered the employ of the General Electric Company in 1901, and, passing through their test department, was assigned to the lighting engineering department, where he remained until 1911. He was then appointed engineer of the Chicago district, and in 1913, was made assistant district manager in addition to his duties as district engineer. Early in 1917 he entered the military service where he remained for two years returning to his company in 1919. In 1924 he was made manager of the engineering department.

PERSONAL MENTION

K. B. Seely, who was previously with Webster & Stone, Inc., is now one of the staff of the Condit Electrical Manufacturing Co., Boston.

Bankim Chandra Ray, who was manager for the Rajkot State Electric Supply Co., India, has been made chief engineer of The Jullundur Electric Supply Co., Ltd., Jullundur City, India.

David S. Rau has been transferred by the Radio Corporation of America from Rocky Point, Long Island, to the High Power Sta., of the Bolinas, California, where he is Assistant Engineer in charge.

D. S. Wegg has left Gilchrist & Co., of Chicago, and is now Assistant Chief, Electrical Equipment Division, Bureau of Foreign & Domestic Commerce, Department of Commerce, Washington.

Newton A. Lewis informs us that he has severed his connections with the Berkshire Electric Co. of Pittsfield, Mass., and has opened up a place of his own, to be known as the Lewis Electric Shop, 19 Darlington Avenue, Kissimmee, Florida.

J. V. Anderson, Associate Member of the Institute, has become Operating Engineer of the Missouri Power & Light Company, Mexico, Mo. Mr, Anderson was previously District Manager of the North Missouri Power Company, Brookfield, Mo.

O. M. Bostwick, New York Representative of the Publicity Department of the General Electric Co., has tendered his resignation, effective January 1st. After a short vacation, Mr. Bostwick will resume his activities in the technical publicity field in New York City.

In the December issue of the Journal notice was given of our member Maurice N. Blakemore opening an office for himself as Financial Counselor and Analyst. Mr. Blakemore's new office is in the Equitable Trust Building, 347 Madison Avenue, New York City.

A letter from Charles Anthony Ablett, Associate Member of the Institute, Manchester, England, states that he and some friends, have recently purchased The Unbreakable Pulley and Millgearing Company, Ltd., as well as the Cooper Roller Bearing Co., Ltd., Mr. Ablett has been appointed Managing Director of the new organization.

John Henry Butters, Associate, who was Chief Engineer and General Manager for the Government Hydroelectric Department, Hobart, Tasmania, has recently been appointed chairman of the Commission to construct and administer the Federal Capital, in which office he will operate from Canberra, Federal Territory, Australia.

On December 1st, Calvin P. Eldred, assumed his new duties as Mechanical Superintendent with Hollingsworth & Vose Co., East Walpole, Mass. Mr. Eldred was previously professor of Electrical Engineering at Rensselaer Polytechnic Institute, but has recently been affiliated with the John A. Manning Paper Co. and the Manning Abrasive Co.

John J. Carty, Vice-President of the American Telephone and Telegraph Company has been made Chairman of an Advisory Board on Research and Development Policies and also Chairman of the Board of Directors of the Bell Telephone Laboratories, Inc. This company is being organized to take over the laboratory work heretofore carried on by the Western Electric Co., it will be owned jointly by the A. T. & T. Co. and the Western Electric

Dr. F. B. Jewett, Vice-President of the Western Electric Co., has been made President of the Bell Telephone Laboratories, Inc., and will be in direct charge of the Research and Development Dept. of the A. T. & T. Co. The addition of Dr. Jewett to the research staff together with the rearrangement of the organization, is made desirable by the very great and increasing magnitude of this research work. Dr. Jewett was President of the A. I. E. E. during the year 1923–24.

Elmer L. Goldsmith, of the firm of Lockwood and Lockwood, Patent Lawyers, Indianapolis, Ind. and Los Angeles, California, has been made officer in charge of the Patent Unit in the Administrative Branch of the Procurement Section, Supply Division office of the Chief of Engineers, for the investigation of Patent claims and inventions of military value, with a view to protecting the United States and including licenses for Government use. Mr. Goldsmith is a member of the Engineers' Reserve Corps.

J. L. Kilpatrick has been elected Vice-President of the Western Electric Company in charge of the Telephone Department and a Director of the company. He succeeds Dr. F. B. Jewett who has become Vice-President of the American Telephone and Telegraph Company. In his new position Mr. Kilpatrick has supervision of the manufacturing, installation and telephone distributing departments of the company. He has also been elected Vice-President and a Director of the International Western Electric Company.

J. L. McQuarrie has been appointed Chief Engineer of the International Western Electric Company. He succeeds E. B. Craft, who has become Vice-President of the Bell Telephone Laboratories Inc. Mr. McQuarrie has held the title of Assistant Chief Engineer, his service with the Western Electric Company having been continuous since 1894. As Assistant Chief Engineer of the International Western Electric Company he has been in touch with communication problems in foreign countries, his most recent trip having taken him to Japan to deal with the situation arising out of the earthquake. Mr. McQuarrie is also a member of the Machinery Club.

Mr. C. E. Skinner, Assistant Director o Engineering Westinghouse Electric & Manufacturing Company, has just been elected Chairman of the American Engineering Standards Committee.

Mr. Skinner is well known throughout the electrical world for his engineering accomplishments and his association with many engineering organizations. He was a member of the Engineering Council which was organized primarily for war work and has since become the American Engineering Council. He was at one time Manager and Vice-President of the American Institute of Electrical Engineers, is at present a member of the Engineering Division of the National Research Council, a member of the American Engineering Council, Chairman of a Special Committee appointed at the request of Mr. Herbert Hoover by the Electrical Manufacturers Council to work with the Department of Commerce and Bureau of Standards; is a member of the Executive Committee of the Standards Committee of the American Institute of Electrical Engineers and of many subcommittees of these various organizations. He has held membership on a number of A. E. S. C committees and was, in 1923, Chairman of their Finance Committee. He is one of the two representatives of the Institute on the Board of Management of the World's Congress of Engineers to be held in Philadelphia in 1926.

Mr. Skinner has been most active in both National Electrical Code and National Electrical Safety Code matters.

He is a native of Ohio and a graduate of the Ohio State University.

Obituary

In the death of John Lyell Harper, Vice-President and Chief Engineer of the Niagara Falls Power Company, the electrical world loses a potent factor. Recognized as one of the world's greastest hydroelectic engineers, his work will remain a lasting monument to his achievement by diligent application to promotion of his profession. Mr. Harper was but fifty-one at the time of his death, November 28th, 1924.

Born in Harpersfield, Delaware Co., New York, September 21, 1873, Mr. Harper's early education was at first in a district school and later in the Stamford Seminary, Stamford, New York. In 1893, the year of his graduation from the Seminary, he won the State scholarship for Cornell University where he entered for the Mechanical Engineering Course. The M. E. degree was won in 1897, with mention on his diploma that he had made a special study of electrical engineering. For four months he worked with the Oregon Improvement Company of Seattle, Washington, and from that time until 1898 he was with the Union Electric Co., of Seattle, which he left to enter the employ of the Twin City Rapid Transit Co., Minneapolis, Minn. Here he was in charge of all their testing of 1200 volt and other underground systems, and the design and erection of switchboards and general operation. With continued progress along hydroelectric lines, Mr. Harper, in 1902, engaged with the Falls Hydraulic Power & Mfg. Co. of Niagara Falls, having responsible charge of all the work done by them. During his first year with them he was Assistant Engineer and for the last four years, Chief Engineer. Mr. Harper was elected to the grade of Associate in the Institute in 1907, but was transferred to full membership very shortly and in 1913 became a Fellow. He was the originator of the plan for the construction on the remedial works in the upper Niagara River to distribute the flow of water over the falls and prevent uneven erosion of the famous Horseshoe Falls. Beside his responsibilities as Vice-President and Chief Engineer of the Niagara Falls Power Company, Mr. Harper found time to carry on scientific investigations on the application of electric service in the electrochemical and electrometallurgical industries at Niagara Falls and developed several patents on electric furnaces. In all his work he maintained the highest ideal of standards which stimulated others as well as doing so much toward accomplishment in his own achievements. He was also a member of the American Society of Civil Engineers, The American Society of Mechanical Engineers and the American Electro-Chemical Society. The untimely termination of his work is indeed a loss to the profession.

James A. Crawford, Associate of the Institute since 1913, died at his home No. 5 Abergeldie Street, Dulwich Hill, Sydney, New South Wales, Australia.

George E. McLaren, Associate, died November 9, at his home 28 Edinburgh Avenue, Hamilton, Ontario.

Walter E. Harrington, Consulting Engineer and Fellow of the Institute died December 12, 1924. Mr. Harrington was born at Wilkesbarre, Pa., June 3, 1866, graduated from the University of Pennsylvania in 1887 and was elected to Associate membership in 1891.

Major Hubert Schurman Wynkoop, Chief Engineer of the Electrical Inspection Div. of Water Supply, Gas and Electricity, City of New York, died suddenly December 13th, 1924.

Born in Yonkers, N. Y. Sept. 20th, 1866, Mr. Wynkoop received his early education at the Adelphi Academy, Brooklyn, from which he graduated in 1884 to enter upon a Mechanical Engineering Course at Stevens Institute in 1884. He obtained his M. E. degree in 1888 and in 1890–1892 served as Assistant District Engineer of the Edison General Electric Co., designing lighting and railway switchboards and electrical distribution systems for them. The following year he was appointed railway expert for the General Electric Co., installing railway and lighting systems at Rome, Ga. From this position he returned to New York in 1894 when he received his appointment as Inspector of Gas and Electricity, Dept. of City Works, Brooklyn, in which capacity he represented the City in electrolysis investigations, acting as electrical adviser to the Commissioner of City Works. In 1898 Mr. Wynkoop became inspector and electrical engineer, organizing and developing the Bureau of Electricity and Gas in the Brooklyn office of the Department of Public Buildings, in full charge of all electrical inspection service for the Borough. In 1908 he was appointed electrical engineer for re-organizing and developing the inspection service in the City of New York, in which capacity he was serving at the time of his death. Mr. Wynkoop belonged to one of the old representative families, was a member of the Sons of the American Revolution and also the Holland Society. He was a member of the American Society of Mechanical Engineers and, since 1912, had been a Fellow of the Institute.

Claire P. Upson, Associate of the Institute, died on December 6th. Mr. Upson was a student of Electrical and Mechanical Engineering at Pratt Institute for two years. He was elected in membership in the Institute June 30th, 1920.

AMERICAN ENGINEERING COUNCIL

ANNUAL MEETING

The annual meeting of the American Engineering Council will be held in Washington, January 16-17, 1925. The Administrative Board of the Council will also convene there on the previous day, January 15th.

Cooperation of all the engineering societies of the United States with the Federal Government in carrying out the provisions of the Clarke-McNary Act and the policy of the engineering profession on the question of consolidating the Public Works functions of the Government, will be among the principal topics considered.

Interpreting the recent action of the Administrative Board as to public works, the president of the Council, James Hartness, says:

"The American Engineering Council will aggressively endeavor to have included in the proposed Division of Public Works all of the construction work now done by the Government, which means, in the light of the present bill pending in Congress,

that we shall endeavor to have included in that bill, by amendment or otherwise, rivers and harbors and the Mississippi River Commission."

There will be a meeting of the Council's Committee on Government Reorganization, as well as of the Advisory Council in Washington the evening of January 15th, to develop concrete plans for carrying out the proposed changes.

Mr. Hartness made public a resolution referred to the Administrative board which "deplored the failure of the Committee on Reorganization of Government Departments to recommend the transfer of rivers and harbors work from the Engineer Corps."

Effort to consolidate the engineering and public works functions of the Government were begun by the engineering profession n 1919.

The importance of the conference and concerted action is evidenced by the fact that the nation's forests are being destroyed at such a rate that if some precautionary measures are not immediately taken, it is bound, Mr. Hartness asserts, to result in a national catastrophe. Dean Mortimer E. Cooley, of the University of Michigan, who is also a leader in the engineering-forestry movement, declares that, "we are rushing at a breakneck speed into a cul-de-sac, which, considering our education and supposed superior intelligence, is the greatest of all human tragedies.—The greatest and most vital problem of our age is the restoration of our forests."

American Engineering Standards Committee

ELECTION OF OFFICERS

At the annual meeting of the American Engineering Standards Committee on December 11, Mr. Charles E. Skinner, a representative of the American Institute of Electrical Engineers, was elected chairman for the year 1925, and Mr. Charles Rufus Harte, representative of the American Electric Railway Association, was elected Vice-Chairman.

The other members of the Executive Committee for the year 1925 are as follows:

Ralph G. Barrows	U. S. War Department
Geo. K. Burgess	U. S. Department of Commerce
John A. Capp	American Society for Testing Materials
Coker F. Clarkson	Society of Automotive Engineers
W. A. E. Doying	The Panama Canal
Stanley G. Flagg, Jr.	American Society of Mechanical Engineers
E. A. Frink	American Railway Association—Engg. Div.
C. S. Gillette	U. S. Navy Department
O. P. Hood	U. S. Department of the Interior
Sullivan W. Jones	American Institute of Architects
Thomas A. MacDonald	U. S. Department of Agriculture
Charles A. Mead	American Society of Civil Engineers
A. H. Moore	Electrical Manufacturers Council
A. Cressy Morrison	Gas Group
Dana Pierce	Fire Protection Group
F. L. Rhodes	Telephone Group
S. G. Rhodes	Electric Light and Power Group
C. F. W. Rys	Association of American Steel Manufacturers
Ethelebert Stewart	U. S. Department of Labor
Geo. C. Stone	American Institute of Mining Engineers
Albert W. Whitney	Safety Group

Mr. Albert W. Whitney, the retiring chairman, is at present in Lima, Peru, attending the Pan American Conference on Standardization.

CONFERENCE IN JANUARY

A conference has been called by the American Engineering Standards Committee, for Tuesday, January 13th, 1925, at 10 a. m., in Room 1001 of the Engineering Societies Building, 29 West 39th St. The purpose of this meeting will be the discussion of Overhead Line Materials, and the meeting is called in accordance with special recommendations of the Committee for the standardization of materials as made by the American Electric Railway Association.

The purpose of the conference is to determine whether the unification and extension of specifications for overhead line material, such as pole line hardware, cross-arms and pins and strain insulators shall be undertaken. It should be noted that the work on the following subjects is already in the hands of a representative committee under A. E. S. C. procedure: Wood poles; tubular steel poles; conductors; insulated wires and cables; annealed, medium and hard-drawn copper wire; zinc coating of iron and steel.

Invitation has been extended to some thirty-nine of the most representative bodies in this special field of service to attend the conference and voice their respective opinions on the importance of the subjects to be discussed.

BOOK REVIEW

THE STANDARD ELECTRICAL DICTIONARY: By T. O'Conor Sloane, A. M., E. M., Ph. D., Author of "Arithmetic of Electricity," etc., etc. Revised and enlarged by Prof. A. E. Watson, of Brown University. The Norman W. Henley Publishing Co., New York, N. Y. 5 by 7 in. Cloth. $5.00.

An electrical dictionary which assumes the proportions of a handbook as well. The author attributes much of its unusual values to its revision and enlargement by Prof. E. Watson, of Brown University. The work contains 790 pages, comprehensively covering the science of electricity in its varying known phases, inclusive of most recent developments, even to the addition of radio terms. It is also profusely illustrated with 497 cuts and diagrams to elucidate the text. It has been said that the modest term "dictionary" but inadequately describes the scope of this book, the definite completeness of which might will prove a valuable adjunct to the library of any electrical engineering student.

SUPERPOWER: Vol. 11. No. 9. Compiled by Lemar T. Beman, A. M., LL. B.; The H. W. Wilson Company, New York, N. Y., Publishers. 5 by 7 in. 89 pp. Cloth binding. Price of 10 issues, $6.00. per single volume 90 cents.

A useful bibliography on power equipment, its resources and applicability. Also containing excerpts from addresses of some eminent authorities on the subject of power conservation.

CROSS INDEX AND GUIDE—1923 National Electrical Code. Pocket size. Price 50 cents. Obtainable through the Asso. of Electrogists-International 15 West 37th St., New York, N. Y.

A comprehensive cross-index of the Code. Efficient for the quick location of any rule.

INDUSTRIAL COAL; PURCHASE, DELIVERY & STORAGE. By American Engineering Council. N. Y., Ronald Press Co., 1924. 419 pp., illus., diagrs., charts, tables, 8 x 6 in., cloth. $5.00. Special prices to members of Societies affiliated with A. E. C., $3.00.

At frequent intervals American industry is embarrassed gravely by inadequate supplies of coal. At the same time the coal industry is unstable and hence not economic. The ills from which it suffers are not entirely due to any one of the groups—producers, carriers and users—interested, nor can any one of them affect a cure unaided. A successful remedy can only come from cooperative action based on mutual recognition of the benefits that will follow stabilization of the coal industry.

Among the remedies proposed is the seasonal storage of coal by consumers. Much attention has been given to this method which has been warmly advocated and as warmly attacked. The lack of any adequate analysis of the problem led the American Engineering Council to undertake a comprehensive study of the problem, in 1923, and the present volume is its report.

The report discusses the production and distribution of coal, practise in coal storage, methods and equipment, deterioration, spontaneous combustion, regional storage, financial problems, etc. Storage by consumers is endorsed and recommended, and it is urged that coal be bought by annual contracts for equal monthly deliveries.

The committee included users, miners and dealers in all sections of the United States. Local conditions were considered carefully. The book should be of great use to all interested in the coal trade, particularly to industrial users of fuel.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES NOVEMBER 1-30, 1924

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

A. S. T. M. Tentative Standards, 1924.

Phila., American Society for Testing Materials, 1924. 763 pp., illus., diagrs., tables, 9 x 6 in., cloth. $8.00, cloth; $7.00, paper.

"Tentative standards" are proposed standards which are printed by the Society for one or more years, in order to elicit criticism, before they are finally revised and recommended for adoption as "standards." The 1924 edition contains 185 tentative specifications, methods of testing and revisions of standards, covering a great variety of commercial products and materials, such as metals, cement and clay products, preservative coatings, lubricants, road materials, fuels, timber, insulating materials, boxes, textile materials, rubber products, etc.

Beton-Kalender, 1925 . . .herausgegeben von der Zeitschrift Beton u. Eisen. Berlin, Wilhelm Ernst u. Sohn, 1924. 2 v., illus., diagrs., tables, 7 x 4 in., v. 1, cloth, v. 2, paper. $1.75.

The 19th issue of this convenient pocket-book has been enlarged and revised so that it forms a convenient, concise summary of the best German practises in concrete construction. Volume one, which is bound, contains the necessary mathematical tables, articles on the strength of concrete, on building materials, statics of structures, the design of reinforced concrete structures, building regulations in various countries, standard specifications, etc. Volume two, in paper covers, is devoted to practical methods of building, and to detailed design of floors, columns, stairways bridges, tanks, walls, etc.

Chapter in American Education; Rensselaer Poltyechnic, 1824-1924.

By Ray Palmer Baker. N. Y., Charles Scribner's Sons, 1924. 170 pp., 8 x 5 in., cloth. $1.00.

A brief, interesting account of the main points in the development of Rensselaer Polytechnic Institute, during its hundred years of existence, in which the national significance of its pioneer work is emphasized and attention is called to its influence on the development of scientific education and research in America, through its curricula and its alumni.

Clerk Maxwell's Electromagnetic Theory.

By H. A. Lorentz. Cambridge, England, University Press, 1923. (Rede Lecture for 1923). 35 pp., 7 x 5 in., paper. 1s 6d. (Gift of Macmillan Co., N. Y.)

Maxwell's "Treatise on Electricity and Magnetism," published in 1873, raised him at once to the first rank of investigators of all ages. In it he proved that electric and magnetic actions can be conceived as being transmitted through a medium and crowned his theory by the revolation that light is an electromagnetic phenomenon.

Professor Lorentz's lecture is a masterly brief review of the Maxwell theory and of its influence on thought since its formulation.

Colloid Chemistry.

By Jerome Alexander. 2nd edition. N. Y., D. Van Nostrand Co., 1924. 208 pp., illus., tables, 8 x 5 in., cloth. $2.00.

A compressed account of the more important general properties of colloids and of some of their practical applications, written in non-technical language, as far as possible. The new edition has been considerably enlarged in both the theoretical and technical sections.

Comprehensive Treatise on Inorganic and Theoretical Chemistry, v. 5.

By J. W. Mellor. Lond. & N. Y., Longmans, Green & Co., 1924. 1004 pp., illus., diagrs., 10 x 6 in., cloth. $20.00.

This fifth volume treats of boron, aluminum, gallium, indium, thallium, scandium, the rare earths and carbon. As in preceding volumes of this treatise, Dr. Mellor has attempted to give complete descriptions of all the known inorganic compounds of these elements and to discuss them where possible, in the light of physical chemistry.

Under each element are discussed its history, its occurrence, extraction, physical and chemical properties and uses, and the properties of its compounds. Copious lists of references are cited, the source being given for all statements. Because of its fullness, the treatise is a necessity to every reference library.

CORROSION OF METALS.

By Ulick R. Evans. N. Y., Longmans, Green & Co., 1924. 212 pp., illus., 9 x 6 in., cloth. $5.00.

In spite of the great practical importance of the subject, there have been but few attempts to gather the scientific principles governing corrosion into a single volume. In the present book the author collects what is known about corrosion and studies the underlying mechanism of the changes that occur. The manner in which the different factors operate is illustrated by practical examples. The book is intended to be of help to engineers and chemists in search of scientific principles by which to interpret their experience, to investigators of corrosion and to students of engineering and chemistry. Is well provided with references to the literature of the subject.

ELECTRIC RAILWAY TRANSPORTATION.

By Henry W. Blake and Walter Jackson. 2d edition. N. Y., McGraw-Hill Book Co., 1924. 449 pp., illus., 9 x 6 in., cloth. $5.00.

A discussion of the transportation methods and practises of American electric railroads covering such important matters as the acceleration of traffic, types of cars, fares, public relations, promotion of traffic, relations with employees, etc. The present edition has been thoroughly revised and reset. A chapter on bus operation has been added and many new examples of recent practise included.

ELECTRICAL CIRCUITS AND MACHINERY, v. 2; Alternating Currents.

By John H. Morecroft and Frederick W. Hehre. N. Y., John Wiley & Sons, 1924. 444 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

A textbook for college students by the Professor and Associate Professor of Electrical Engineering at Columbia University. Gives more attention to the polyphase circuit then is customary in books of this kind and also is unusual in discussing the types and actions of alternating-current instruments. A chapter is devoted to transmission lines.

ELECTRICAL DRAFTING AND DESIGN.

By Calvin C. Bishop. N. Y., McGraw-Hill Book Co., 1924. 165 pp., diagrs., tables, 9 x 6 in., cloth. $2.00.

A supplement to the usual course in mechanical drawing, which covers the principles and methods peculiar to the drafting done in the office of an electrical engineer, contractor or power company. Includes such subjects as switchboards, residence wiring, outdoor substations, motor wiring, lighting, etc.

ELEMENTS OF MACHINE DESIGN.

By S. J. Board and E. O. Waters. N. Y., D. Van Nostrand Co. 1924. 323 pp., illus., diagrs., tables, 9 x 6 in., cloth. $2.50.

Designed to fill the gap between engineering drawing and advanced machine design. Intended for students in technical schools and for young draftsmen preparing themselves as designers. The authors believe that success in designing machinery depends on the mastery of a few fundamental principles of mechanics, mechanism, strength of materials and the technique of drafting, and the coordination of these with a well-trained sense of proportion. They have therefore aimed at a logical, consistent development of approved methods of design, applied to the more common elements of machine construction.

EYE HAZARDS IN INDUSTRIAL OCCUPATIONS.

By Louis Resnick and Lewis H. Carris. N. Y., National Committee for the Prevention of Blindness. 1924. 247 pp., illus., tables, 9 x 6 in., paper. Paper, with linen backing, $1.50; Fabrikoid, $2.50.

This report issued by the National Committee for the Prevention of Blindness, is the result of two years' study of eye hazards in industrial occupations and of methods for their elimination. It is a thorough review of the various diseases and accidents to which labor is exposed, of the approved safety devices and methods of shop lighting, and of safety practises in various companies. A list of references is included.

GENERATOR AND MOTOR EXAMPLES.

By F. E. Austin. Hanover, N. H., The Author, 1924. 108 pp., diagrs., tables, 8 x 5 in., cloth. $2.50.

A concise presentation of the principles of design for students of engineering. Both quantitative and qualitative characteristics are given careful consideration, and constant attention is paid to the ultimate or commercial efficiency of the various machines discussed.

HOW TO MAKE HIGH-PRESSURE TRANSFORMERS.

By F. E. Austin. 3rd edition. Hanover, N. H., The Author, 1924. 75 pp., illus., diagrs., tables, 8 x 5 in., cloth. $1.25.

Gives detailed directions for building three transformers, a 1 kilowatt 20,000 volt, a 3 kilowatt 20,000 volt and a 1 kilowatt 4000 volt. Drawings and photographs illustrate the text.

JOHN A. BRASHEAR . . . AUTOBIOGRAPHY; edited by W. Lucien Scaife.

N. Y., American Society of Mechanical Engineers, 1924. 262 pp., illus., Port., 9 x 6 in., cloth. $4.25.

The autobiography of a man without formal education who started life as a journeyman machinist and rose to eminence through his great mechanical skill, as the foremost maker of astronomical lenses of his time. Dr. Brashear tells the story of his early life, of the growth of his interest in astromony and of his struggles to build a telescope, in interesting graphic language. His later career as a manufacturer, as an educator and as a man of public affairs is covered adequately to the close of his accounts in 1917. The editor has added a number of letters that continue the story to the time of his death in 1920.

KINETIC THEORY OF GASES.

By Eugéne Bloch. N. Y., E. P. Dutton & Co., n. d. 178 pp., tables, 8 x 5 in., cloth. $3.00.

The kinetic theory of gases is merely a branch of the molecular theory of matter, but it is the most completely developed branch and the one in which reasoning and calculation can be most simplified. In the present book Professor Bloch outlines the principal mean properties that have been mathematically deduced from observed molecular motion and presents the principles of the theory in a clear manner. Mathematics has been simplified as much as possible. The book is intended as an introduction to the subject and includes a list of books for those who wish to pursue the subject further.

LEHRBUCH DER NOMOGRAPHIE.

By H. Schwerdt. Berlin, Julius Springer, 1924. 267 pp., diagrs., 8 x 6 in., boards. 12, 90 gm.

A thorough textbook for serious students of nomography. While it has the primary purpose of introducing the student to practise in nomographic problems and acquainting him with the most important aids, it also pays attention to the connection of this branch of applied mathematics with its neighbors. The book develops the fundamental principles so that they may be applied and illustrates them by detailed application to important cases. Special attention is paid to accuracy in charts.

MEASUREMENT OF FLUID VELOCITY AND PRESSURE.

By J. R. Pannell; edited by R. A. Frazer. Lond., Edward Arnold & Co., 1924. 135 pp., illus., diagrs., 9 x 6 in. cloth. $3.50. (Gift of Longmans Green & Co.).

The author, who was killed by the fall of the British airship R-38 in 1921, had been engaged for many years in aerodynamic research and had devoted his leisure to the preparation of the present treatise, which he left practically complete. The book treats of the various types of instruments, pressure-tube, moving-part and hot-wire anemometers, direction and velocity meters, ship logs, and manometers which have been devised for measuring the velocity and pressure of fluids, and also contains a chapter on the laws governing the flow of fluids in circular pipes.

MESURES TELEGRAPHIQUES ET TELEPHONIQUES.

By Georges Valensi. Paris, Gauthier-Villars et Cie., 1924. 277 pp., diagrs., 9 x 6 in., paper. 40 fr.

Covers the course of instruction given since 1919 to those student engineers in the French Department of Posts and Telegraphs, who have graduated from the Electrical High School before undertaking specialized study. The course initiates them in the special telegraphic and telephonic measurements which will furnish a solid experimental foundation for the technical work which they will have to carry out or direct as engineers in the service.

L'ORIGINE TOURBILLONNAIRE DE L'ATOME ET SES CONSEQUENCES.

By Jean Varin D'Ainvelle. Paris, Gauthier-Villars et Cie., [1924]. 215 pp., 10 x 6 in., paper, 20 fr.

In this work the author undertakes to deduce the laws of physics from the hypothesis that atoms are vortex tubes in the

ether, a fluid to which no special properties, such as abnormal rigidity, are attributed, but which resembles ordinary fluids, being viscous, compressible and subject to changes in temperature. These vortex tubes are cylindrical, of finite length and carry fixed quantities of electricity and magnetism. They are hydrogen atoms, from which the other atoms are derived.

Various facts, such as the emission of x-rays, photo-electric effects, the electromagnetic theory of light, valence, the Einstein theory, the theory of heat, the solar system, are examined and explained on the basis of this hypothesis.

Power Plant Machinery, vol. 2; Details and Accessories.

By Walter H. James and M. W. Dale. N. Y., John Wiley & Sons, 1924. 267 pp., illus., 9 x 6 in., cloth. $3.00.

The second of two volumes, intended to form a connecting link between the study of mechanism and heat engineering, in which are generally discussed the principal machines used in a steam power-plant, not including boilers, stokers and machinery for handling coal and ashes. The present volume is largely descriptive. It gives in detail the construction of the various parts of reciprocating engines and treats of turbines, compressors, pumps, steering engines, reversing gears and steam and pneumatic tools. Various auxiliaries, such as feed-water heaters, condensers, cooling towers and spray ponds, together with such devices as pulsometers, air lifts and hydraulic rams, are also treated.

Practical Radio.

By James A. Moyer and J. F. Wostrel. N. Y., McGraw-Hill Book Co., 1924. 249 pp., illus., diagrs., 8 x 5 in., cloth. $1.75.

The object of this book is to present the fundamentals of the subject so simply and clearly that any person of average training will be able to understand and apply them. Crystal and vacuum tube sets, sources of electricity, and methods of audio-frequency and radio-frequency amplification are explained. There are chapters on the selection and operation of receiving sets and on troubles and remedies as well as directions and working drawings for a number of popular receiving sets.

Principles and Applications of Electrochemistry, v. 1, Principles.

By H. Jermain Creighton. N. Y., John Wiley & Sons, 1924. 446 pp., illus., tables, 9 x 6 in., cloth. $4.00.

The first of two volumes containing a systematic course of instruction for chemical students, intended also for use as a reference book. Is the first book in English, according to the author, which takes cognizance of the new knowledge which has accumulated in this field during the past decade. The present volume deals with the principles and general theory of the subject.

Principles of Applied Electrochemistry.

By A. J. Allmand. 2d edition, rev. & enl. by the author and H. J. T. Ellingham. N. Y., Longmans, Green & Co., 1924 727 pp., illus., diagrs., tables, 9 x 6 in., cloth. $10.50.

A textbook for students and a reference book for those in electrochemical industries. Part one treats of theory and general matters; part two of special technical applications and processes; such as the refining of metals, electric steel making, the fixation of nitrogen, the alkali industries, etc. Part one remains about the length of the first edition, but several chapters on physical chemistry have been deleted and replaced by material on irreversible electrode phenomena. Part has been considerably enlarged by the inclusion of new methods.

La Soudure Electrique A L'Arc Metallique.

By S. Frimaudeau. Paris, Gauthier-Villars et Cie, 1924. 135 pp., illus., diagrs., 7 x 5 in., paper. 10 fr.

A concise handbook of practical information on methods of arc welding, on welding machines and on the theory underlying the process.

Small Electric Generating Sets Employing Internal Combustion Engines.

By W. Wilson. Lond., Ernest Benn, 1924. 161 pp., illus., diagrs., 9 x 6 in., cloth. 18 s.

This book is concerned primarily with small electric plants of from 0.75 K. W. to 6 K. W. capacity, intended for domestic power, small shops or for portable apparatus. It has been planned to assist engineers, architects and prospective buyers in the selection, installation and operation of such plants. The author has avoided intricate technical details as far as possible, without going to the opposite extreme of being too elementary. The equipment described is that in the British market.

Structural Engineering, Strength of Materials.

By George F. Swain. N. Y., McGraw-Hill Book Co., 1924. 569 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

The present volume is the first of a series of four treating of the theory and design of structures, which will embody the course that the writer has been giving for many years, with amplification intended to make it a fairly complete treatise for engineers. It aims to give a clear, complete and simple discussion of the fundamental principles of the strength of materials applicable to the design of various kinds of structures, including masonry and concrete, as well as framed structures, and to occupy a middle ground between the brief textbooks and the encyclopedic works of reference. It goes beyond the limits of the curricula of most engineering schools and places the student in a position to pursue the subject further.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Industrial Applications of Eectric Heating, by Wirt S. Scott, Westinghouse Electric & Mfg. Co. The speaker pointed out that the success of electric heating was due chiefly to the development of durable chrome resistance material. The lecture was illustrated with lantern slides. December 4. Attendance 42.

Atlanta

The Storage Battery—Its Part in Modern Social and Business Life, by Chas. W. Bell, The Electric Storage Battery Company. The lecture was illustrated by lantern slides. December 8. Attendance 32.

Cincinnati

The Properties of Speech, Music and Noise, and Their Relation to Electrical Communication, by Dr. Harvey Fletcher, Western Electric Co. Joint meeting with the Cincinnati Engineers' Club. November 20. Attendance 260.

Reminiscences of Twelve Years Engineering Experience in the Near East, by Prof. L. A. Scipio, Robert College, Constantinople. Joint meeting with American Society of Mechanical Engineers. December 11. Attendance 65.

Cleveland

Inspection trip to Ohio Insulator Company. A. O. Austin, Chief Engineer, gave a short talk on insulator manufacture, together with the causes of flashovers and the points at which they occur. A number of demonstrations were given. November 20. Attendance 169.

Connecticut

The Fynn-Weichsel Motor, by E. W. Goldschmidt, The Wagner Electric Corp. The lecture was illustrated by slides and

Common Sleeve Bearings, by J. L. Brown, Westinghouse Electric & Mfg. Co. The lecture was illustrated by slides. Mr. G. Faccioli, also addressed the meeting, describing briefly the offering of a prize for "First Papers" in the District. He was followed by Prof. H. B. Smith, who presented the certificate and honorarium to Prof. H. M. Turner, Yale University, whose prize-winning paper was on "The Transient Visualizer." Refreshments were served. November 20. Attendance 100.

Denver

Inspection trip to Valmont Plant of the Public Service Company of Colorado. V. L. Board outlined the electric power system of the Public Service Company and R. F. Throme gave a very clear description of the technical make-up of the Valmont Plant. Luncheon was served. November 29. Attendance 91.

Detroit-Ann Arbor

Problems in Power Transmission, by R. E. Doherty, General Electric Co. The lecture was illustrated by slides. November 18. Attendance 150.

The Uviarc Testing Cabinet, by L. J. Buttolph, Cooper Hewitt Electric Co. The demonstration and lecture were illustrated with slides. Joint meeting with American Institute of Chemical Engineers, American Chemical Society, Society of Industrial Engineers, Industrial Electrical Engineers Society and Detroit Engineering Society. November 21. Attendance 60.

Erie

Freight Electrification, by E. E. Kimball, General Electric Co. The talk was illustrated with moving pictures and lantern slides. November 18. Attendance 144.

Fort Wayne

Inspection trip to Spy Run Power Plant of the Indiana Service Corporation. R. L. Fitzgerald addressed the meeting. November 20. Attendance 50.

Lehigh Valley

The Distribution and Consumption of Electrical Power by a Group of Anthracite Coal Mines, by G. N. Kennedy.

Delivery of Power, by N. G. Reinicker, Pennsylvania Power & Light Co. and

The American Institute of Electrical Engineers, by L. W. W. Morrow, Chairman, National Meetings and Papers Committee. November 21. Attendance 262.

Los Angeles

The Properties of Speech, Music and Noise, and Their Relation to Electrical Communication, by Dr. Harvey Fletcher, Western Electric Co. November 7. Attendance 300.

Madison

Organization and Development of the Wisconsin Telephone Co., by John O'Day. A switchboard demonstration was given.

Telephone Transmission, by H. R. Huntley and

Industrial Training of Telephone Employees, by H. S. Day. December 4. Attendance 50.

New York

Aerial Mapping for Civil and Military Purposes, by Girard Matthes, Consulting Engineer and Specialist on Aerial Mapping; Major James W. Bagley, Corps of Engineers, U. S. A., and Farley Osgood, President, A. I. E. E. The three speakers covered the various factors to be taken into consideration in building up maps from aerial photographs, the uses which have been made of aerial mapping, the various types of cameras in use today. Most of these types were on exhibition. Meeting was held jointly with New York Section of A. S. C. E., the Municipal Engineers of New York, and the N. Y. Post, American Society of Military Engineers. A discussion engaged in by several engineers followed the scheduled talks. Preceding the regular meeting a very interesting motion picture was shown, depicting the story of the "Lost Battalion" under Colonel Whittelsey. December 17, 1924. Attendance 530.

Pittsburgh

Factory Built and Completely Assembled Switching Equipments, by K. C. Randall, Westinghouse Electric & Mfg. Co. An inspection trip was made through the factory in which truck-type switchboards are manufactured. November 18. Attendance 332.

Pittsfield

City-Manager Form of Government, by H. W. Dodds, Secretary, Municipal League, New York City. November 18. Attendance 150.

The Design and Manufacture of Electric Cables, by W. C. Hayman, General Electric Co.,

Features of Design and Operating Requirements, by Wallace S. Clark, General Electric Co.,

High-Voltage Cable Joints & Terminals, by C. G. Mansfield, General Electric Co. and

Cable-Insulation Research Problems, by F. M. Clark, General Electric Co. December 2. Attendance 150.

Portland

The Most Revolutionary Theory of Modern Physics, by Dr. A. A. Knowlton, Reed College. Motion pictures were also shown and refreshments were served. Joint meeting with National Electric Light Association. November 12. Attendance 75.

Providence

The Mercury Boiler and Turbine for the Generation of Power, by B. P. Coulson, General Electric Co. Joint meeting with American Society of Mechanical Engineers. November 14. Attendance 75.

Rochester

The Fynn-Weichsel Motor, by E. W. Goldschmidt, Wagner Electric Corporation. The speaker showed a very interesting motion picture on the evolution of power application. He then described "power factor," which was illustrated with lantern-slide diagrams. December 5. Attendance 75.

San Francisco

Lightning; Its Formation and Characteristics, by F. W. Peek, Jr., General Electric Co. The talk was illustrated by moving pictures and slides. October 20. Attendance 135.

Demonstration of Properties of Speech, Music and Noise, and Their Relation to Electrical Communication, by Dr. Harvey Fletcher, Western Electric Co. and

An Important Message to Our Members, by Dr. Farley Osgood, President, A. I. E. E. November 5. Attendance 450.

Schenectady

A Survey of Current Progress in Radio Engineering, by Dr. J. H. Dellinger, Bureau of Standards. November 7. Attendance 310.

Seattle

Banquet. Talks were given by Dr. Farley Osgood, President, A. I. E. E., and E. H. Hubert, Secretary, National Meetings and Papers Committee. October 24. Attendance 66.

Springfield

Radio History, by W. A. Ready, National Company and

Tuned Radio-Frequency Transformers, by Glenn H. Browning, National Company. November 24. Attendance 89.

Toledo

A talk was given by M. J. Riggs, American Bridge Co. He exhibited wooden models of various types of bridges and lantern slides of notable American and European bridges and of bridges under construction. November 19. Attendance 32.

Toronto

Radio, by C. L. Richardson, Canadian General Electric Co. Informal dance. Refreshments were served. November 13. Attendance 150.

A talk was given by W. E. Wickenden, Director of Investigation, Society for the Promotion of Engineering Education. November 17. Attendance 35.

Questions of Practical Interest in Transmission and Distribution, by H. B. Dwight, Canadian Westinghouse Co. The lecture was illustrated with slides. November 21. Attendance 90.

Urbana

Problems in Long-Distance Power Transmission, by R. E. Doherty, General Electric Co. November 14. Attendance 75.

Utah

Properties of Speech, Music and Noise, and Their Relations to Electrical Communication, by Dr. Harvey Fletcher. October 29. Attendance 122.

Vancouver

Inspection trip to Ballantyne Pier and No. 2 Government Grain Elevator. November 8. Attendance 35.

The World Power Conference, by Frank Sawford. December 5. Attendance 21.

Worcester

Design and Construction of Cahokia Power Station, by H. W. Eales. December 3. Attendance 75.

BRANCH MEETINGS

University of Alabama

A moving picture, entitled "Queen of the Waves," was shown. A lecture on this film was given by Henry S. St. John, student. November 25. Attendance 26.

Electrical Locomotives Vs. Steam Locomotives. A debate—the result being in favor of steam locomotives. The following officers were elected: President, Charles M. Lang; Secretary-Treasurer, Clay S. Comfeaux. December 9. Attendance 53.

University of Arizona

Talks were given by Messrs. Jefferys, Anderson, Coggins, Blair, Butler, and Cotrell. September 24. Attendance 21.

Practical Side of Electrical Engineering, by Sam Headman, Tucson Gas and Electric Co. A movie was also shown. October 15. Attendance 19.

The Resistence of Copper at High Temperatures, by Professor Paul Cloke. November 25. Attendance 19.

University of Arkansas

Manufacturing Processes, by Porter Cleveland, student,

Relations of Public Utilities, by M. J. Thrasher, student and

Comparative Efficiencies of Diesel and Steam Engines, by C. T. Marak, student. November 18. Attendance 32.

California Institute of Technology

The Principles and Applications of the Klydonograph, by P. B. Garrett, Westinghouse Electric & Mfg. Co. October 29. Attendance 19.

Apprentice Courses Offered by the Westinghouse Electric & Mfg. Company, by J. J. Devoe. Refreshments were served. November 5. Attendance 29.

Business Meeting. November 26. Attendance 29.

Carnegie Institute of Technology

Electric Drive for Rolling Mills, R. H. Wright, Westinghouse Electric and Mfg. Co. The talk was illustrated by lantern slides. November 4. Attendance 31.

The Construction Features of the C. M. and St. P. Electric Locomotive, by J. M. Kelly, student. December 3. Attendance 36.

Case School of Applied Science

Talks were given by Professor Dates, Dr. Huxley, Mr. Owens and Mr. Wertz. November 14. Attendance 45.

Catholic University of America

Business Meeting. The following officers were elected: President, K. T. Williamson; Vice-President, E. J. Twomey, Secretary, G. B. Mangan, and Treasurer, J. W. Dolan. October 15. Attendance 14.

Principles Underlying Radio Communication, by Professor T. J. MacKavanagh. Refreshments were served. October 23. Attendance 23.

Development of Underground Cable, by Mr. Kirchener, Standard Underground Cable Co. Refreshments were served. November 19. Attendance 24.

University of Cincinnati

Resistances of Various Types for Radio Use, by H. F. Jaeckel. Allen-Brady Co. The lecture was illustrated. November 12. Attendance 56.

Clemson Agricultural College

The Advantages of thé A. I. E. E., by Professors Carpenter, Clark, Dargan, Watkins and Rhodes. November 13. Attendance 47.

University of Colorado

Stadiums of Greece and Rome, by F. B. R. Hellems,

Modern Stadiums, by W. C. Huntington and

University of Colorado Stadium, by Waldo Brockway. The talks were illustrated by slides. Joint meeting with the American Society of Civil Engineers, the American Society of Mechanical Engineers and the Colorado Society of Engineers. November 22. Attendance 125.

University of Denver

Apprenticeship Work with the Westinghouse Electric & Mfg. Co., by Mr. Trudgian. November 14. Attendance 35.

Some Notes on Street Lighting, by Ralph L. Kuhler, student. December 5. Attendance 21.

Georgia School of Technology

The Electrification of Railways, by W. W. Ballew, Westinghouse Electric & Mfg. Co. November 4. Attendance 55.

University of Idaho

Business Meeting. The following officers were elected: President, Harrison Armstrong; Vice-President, William Killimann; Secretary-Treasurer, Richard C. Beam. November 6. Attendance 14.

Engineering Aptitude, by Professor J. H. Johnson. December 2. Attendance 8.

Kansas State College

The Method of Attacking Engineering Problems, by R. E. Doherty, General Electric Co. November 3. Attendance 95.

Making the Most of Artificial Illumination, by R. M. Hill, student.

Hydroelectric Equipment of Muscle Shoals, by Leo Schutte, student. November 24. Attendance 73.

University of Kentucky

Inspection trip to Dix River, where a hydroelectric project is being constructed. The following officers were elected: President, R. K. Giovannoli; Secretary, J. M. Willis. October 20. Attendance 22.

Lehigh University

Transformers and Their Superpower Distribution, by H. O. Stevens, General Electric Co.

My Experience on the S. S. Leviathan, by F. C. Beck, student. Refreshments were served. November 14. Attendance 85.

Speed Control of Electric Motors, by F. R. Fishback, Electric Controller and Mfg. Co. and

Electrolytic Rectifiers, by C. W. Allen, student. Refreshments were served. December 12. Attendance 70.

University of Maine

Business Meeting. The following officers were elected: Chairman, Robert N. Haskell; Vice-Chairman, Cecil V. Leighton; Secretary, Sidney B. Coleman, Treasurer, Mansfield Packard. November 6.

Operation of Hydroelectric Stations during the Freshet Period, by Arthur L. Davis, Bangor Railway & Electric Co. November 20.

Massachusetts Institute of Technology

The Manufacture and Use of Electric Cables, by E. W. Davis, Simplex Wire and Cable Co. November 20. Attendance 29.

Inspection trip to Simplex Wire & Cable Company in Cambridge. December 2. Attendance 15.

The New Weymouth Station of the Boston Edison Co., by H. W. Ford, Stone & Webster Co. A moving picture, entitled "Power," was also shown. December 4. Attendance 95.

Mechanical Analogies of Electrical Phenomena, by Theodore Taylor, student. December 11. Attendance 12.

Michigan Agricultural College

The Nature of the Consumer's Power Company, by H. G. Burton and

Design of Small Substations, by E. V. S. Dayles, Consumers' Power Co. November 25. Attendance 45.

University of Michigan

Controlling Electric Motors, by F.R. Fishback, Electric Controller & Mfg. Co. The lecture was illustrated with slides. November 19. Attendance 47.

Two motion pictures were shown, entitled respectively, "The Pace of Progress" and "Along the Green Bay Trail." December 3. Attendance 178.

University of Missouri

Talks on Summer experiences at different electrical companies were given by the following students: R. Stokes, C. C. Greim, W. R. McMillan, O. S. McDaniel and J. S. Glazebrook. October 13. Attendance 38.

The Development of a Suspension-Type Insulator, by H. P. Strieder, student. November 24. Attendance 35.

University of Nebraska

Inspection trip to the Electric and Gas Plants supplying the City of Lincoln. October 18. Attendance 80.

Social Meeting. Short talks were given. Refreshments were served. October 9. Attendance 112.

Talks were given by some of the students on their Summer employment with industrial companies. November 7. Attendance 50.

University of North Dakota

Business Meeting. November 17. Attendance 18.

The Vacuum-Tube Relay, by John Hutcheson,

The Possibilities for an Engineer Outside of Strictly Engineering Fields, by D. R. Jenkins and

The Telephone Game, by Warren Dunham. December 1. Attendance 30.

Ohio Northern University

Electrical Equipment in Mines, by Mr. Young and

Porcelain and the Machinery Used in Its Manufacture, by C. Z. Eatherton. November 19. Attendance 31.

Business Meeting. December 3. Attendance 31.

Ohio State University

Business Meeting. November 14. Attendance 35.

Oklahoma Agricultural and Mechanical College

Two moving pictures, entitled respectively, "Automatic Substations for Railways" and "Distributer Type of Supervisory Systems," were shown. November 13. Attendance 79.

University of Pennsylvania

Social Meeting. Talks were given by Dean Pender and other Faculty members. October 10. Attendance 64.

Business Meeting. November 4. Attendance 83.

Some Electrical Heresies, by Dr. Carl Hering. A minstrel show was given by the Moore School students. Refreshments were served. November 21. Attendance 66.

Business Meeting. November 25. Attendance 12.

University of Pittsburgh

Safety Devices in New York Subways, by L. E. Endsley. Joint meeting of Engineering Societies. November 7. Attendance 60.

Superpower, by E. H. Powell and

Internal-Combustion Electric Locomotive, by G. H. Boggs. November 14. Attendance 28.

Commercial and Engineering Possibilities in South America, by Q. Pesquera and

Superpower in the West, by W. M. Alexander. November 21. Attendance 30.

Purdue University

The Control of Electric Motors, by F. R. Fishback, Electric Controller and Mfg. Co. The talk was illustrated. November 18. Attendance 121.

Rensselaer Polytechnic Institute

Talks were given by sixteen students on their work during the Summer. November 11. Attendance 70.

Business Meeting. The following officers were elected: Chairman, Dr. F. M. Sebast; Secretary-Treasurer, Charles E. Daniels. December 3. Attendance 40.

Alchemy: Ancient and Modern, by Drs. Hunter and Patterson. December 9. Attendance 110.

Rhode Island State College

Life of Dr. Steinmetz, by John Harvey, Jr. A motion picture film, entitled "Remote Control," was shown. November 6. Attendance 16.

Life of Dr. B. G. Lamme, by Stanley C. Bliss and

Edison's First Electrical Central Station, by Raymond S. Sutcliffe. This lecture was illustrated. November 20. Attendance 18.

University of South Dakota

The Development of the Transformer. The lecture was illustrated. November 20. Attendance 25.

University of Texas

The Super-power System in the U. S., by Professor J. M. Bryant. November 19. Attendance 34.

The Purpose of an Education, by Professor Correll. December 3. Attendance 16.

Virginia Military Institute

High Quality Transmission Reproduction of Speech and Music, by W. A. Hopkins,

History and Purpose of the A. I. E. E., by H. F. Watson and

Student Chapter of A. I. E. E. at Virginia Military Institute, by Col. S. W. Anderson. November 19. Attendance 61.

University of Virginia

History of, and Benefits to be Derived from Local Branch, by Walter Sheldon Rodman. Refreshments were served. November 4. Attendance 17.

Story of Compressed Air, by Arthur F. Macconochie. November 21. Attendance 40.

State College of Washington

Business Meeting. The following officers were elected: President, R. P. Fridlund; Vice-President, A. J. Sorenson; Secretary, C. H. Backus; Treasurer, C. J. Calbick; Reporter, D. H. Cloud; Executive Council, F. C. Sarchet and D. D. Miller. October 8. Attendance 30.

The National A. I. E. E., by Dean H. V. Carpenter. November 25. Attendance 41.

University of Washington

The Lake Cushman Hydroelectric Project, by J. L. Stannard and A. F. Darland, both of the Tacoma Municipal Power Company. The talk was illustrated with slides showing all phases of the construction and central station design. Joint meeting with A. S. M. E. November 18. Attendance 39.

Washington University

Business Meeting. November 24. Attendance 14.

High-Voltage Research Work at Stanford University, by Professor J. C. Clark, Iowa State University and

The Engineer in Court, by Professor J. M. Bryant. December 5. Attendance 58.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—Samuel Brown, 2729 Ocean Parkway, Brooklyn, N. Y.
2.—E. V. Charleson, P. O. Box 11, Woodville, Pa.
3.—Thomas R. Curtis, 3210 Arthington St., Chicago, Ill.
4.—David O. Dolen, c/o Commonwealth Edison Co., Sub-sta. Dept., 72 W. Adams St., Chicago, Ill.
5.—Ed. J. Ensweiler, 865–25th St., Milwaukee, Wis.
6.—W. C. Finely, 211 John St., Oakland, Calif.
7.—Frank Goldenberg, 2821 Windsor Ave., Baltimore, Md.
8.—A. Fred Hansen, 462 West 37th St., Los Angeles, Calif.
9.—T. J. Hodge, Eng. Dept., Memphis Pr. & Lt. Co., Memphis, Tenn.
10.—H. H. Hurd, 14302 Euclid Ave., East Cleveland, Ohio.
11.—W. W. Johnson, 320 So. 19th Ave., East, Duluth, Minn.
12.—E. V. Karlsen, c/o Cons. Copper Mines Corp. Kimberly, Nev.
13.—William G. Keith, 4840 N. Kimball Ave., Chicago, Ill.
14.—George J. Lechner, The Edward-Johns Co., 1740 East Twelfth St., Cleveland, Ohio.
15.—H. S. Logan, Masonic Club, Portland, Ore.
16.—F. M. Meyerend, New York Edison Co., 555 Tremont Ave., Bronx, New York, N. Y.
17.—James D. Newman, Dallas Pr. & Lt. Co., 1410 Jackson St., Dallas, Texas.
18.—J. C. Peterson, 323 W. Navarre St., South Bend, Ind.
19.—Geo. W. Powell, Erection Dept., Allis Chalmers Mfg. Co., Milwaukee, Wis.
20.—W. B. Pradhan, L. E. E., Gamdevi Kennedy Bridge, Bombay No. 7, India.
21.—Wm. G. Shull, St. George Hotel, 60th & Blackstone Ave., Chicago, Ill.
22.—Thomas C. Shwab, 166 Rutland Road, Brooklyn, N. Y.
23.—Foster Strong, 57 So. 7th East St., Salt Lake City, Utah.
24.—Thomas Whitmore, 1803 W. Pacific Ave., Spokane, Wash.
25.—O. B. Wooten, Texas A. & M. College, College Station, Texas.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

DESIGNING ENGINEER, familiar with experimental and development work A C motors. Apply by letter with full details of experience, salary, etc. Location, Middlewest. R-5166.

ELECTRICAL DESIGNER in connection with elevator signals, control and electrical dumbwaiter work. Man who has been with one of the large electric companies such as General Electric, Westinghouse, etc., preferred. Application by letter stating age, education and experience in detail. Salary $5000. Location, New Jersey. R-5251.

MECHANICAL ENGINEER, college graduate about 30, with good engineering experience, for first assistant to head of mechanical engineering department in strong technical school. Salary $2500 to $3000 for academic year. Permanency and advancement. Previous teaching experience not necessary. Give full personal and professional particulars. Location, New York City. R-5051.

RADIO ENGINEER: Qualifications for this position are described in a display advertisement on page 12 of the advertising section.

ELECTRICAL ENGINEER with good technical training and about eight years' experience in electric light power and railway public utility work. Location large city in Brazil. In applying give full particulars regarding self and experience, also stating salary desired and when available. B-5272.

ELECTRICAL ENGINEER, college graduate, about ten years' experience in general public utility work desired by company operating foreign electric light power and railway utilities. Apply by letter stating full particulars of experience, when available and salary desired. Location, Toronto, Canada. R-5273.

TELEPHONE-RADIO ENGINEER, having had experience on oscillograph equipment on high frequencies, impedance runs of voice frequencies, and otherwise broad experience in telephone and radio engineering. Permanent position with firmly established private Chicago laboratory for right man. Salary commensurate with ability. Reply by letter stating age, education, details of experience, names of firms, and salary desired. Location, Middlewest. R-5302.

MEN AVAILABLE

M. I. T. GRADUATE in electro-chemical engineering, two and one half years' experience in Government Radio Laboratory. Good mechanic with original practical ideas. Interested in manufacturing. Location unimportant. $2000. Single. B-9027.

ELECTRICAL ENGINEER, technical education, experienced in the design of medium size polyphase induction and direct current motors. Desires position with an electrical motor manufacturing company, as motor designer. Twenty-four years experience in designing, experimenting and development of alternating and direct current motors, investigation, service work, electrical construction and maintenance. B-9016

RECENT ELECTRICAL ENGINEERING GRADUATE, would like to obtain position with firm having hydro-electric or maintenance work. Has had about one year surveying and construction experience. Also some electrical construction experience. B-9032.

ELECTRICAL ENGINEERING GRADUATE, about four years out of college, having had experience in testing, switchboard engineering and designing of substations and power plants. Desires responsible position with public utility or manufacturing concern. Minimum salary $2400. Location immaterial. Now available. B-8852.

ELECTRICAL-MECHANICAL ENGINEER, age 38, member A. I. E.E., A. S. M. E. Employed at present. Desires relocation in East, July 1925. Proficient in patent perfecting, remodeling, simplifying, research, efficiency, safety, production, cost and fire prevention. B-9035.

ELECTRICAL ENGINEERING GRADUATE 1920, age 26, desires a change of location from the East to the Middlewest. G. E. Test experience one year and a half; two and one half years with large public utility. General training covers routine of different departments of public utility company. Specific training in distribution layouts, including revamps, line extensions and testing of distribution equipment. Available on three weeks' notice. B-9040.

ELECTRICAL ENGINEER-MANAGER, technical training both mechanical and electrical. Five years switchboard engineering, two and a half years power plant layout, five years in charge of electrical superintendent of construction of large power plants. Prefer position as manager of distribution and operation for power operating company. B-9039.

ELECTRICAL ENGINEER available. 1923 graduate from university abroad. One half year test and two and a half years as construction engineer and designer of power plants and substations. Have been employed one year by large public utility company in East, but desires change to position offering opportunity for advancement. B-8781.

DISTRIBUTION ENGINEER, ten years' experience in the operation and management of public utilities. Well acquainted with modern power sales methods and accounting of same. Experienced in valuation and reporting on electrical systems both technical and financial. B-9061.

RECENT E. E. GRADUATE, age 23, single, desires position as student engineer with large manufacturing concern to gain practical experience. Will locate anywhere. Associate member of A. I. E. E. B-9062.

ELECTRICAL ENGINEER, age 24, B.S. from M. I. T. 1924, also A. B. Williams 1922, desires start in electrical engineering, preferably in electric railway work so as to acquire experience. Will work hard. B-9067.

M. I. T. GRADUATE IN ELECTRICAL ENGINEERING, young, with intensive training in production, testing and research work on high and low voltage cables, wishes position in electrical engineering or manufacturing. Has sound knowledge of general electrical engineering and of production economics. Prefers position in or near Boston. B-9077.

ELECTRICAL ENGINEER, age 36, married, graduate Bliss Electrical School, fourteen years' experience with light and power utilities. Experienced in hydro-electric design and construction. Four years in charge of maintenance and construction on transmission system. Desires similar connection with progressive public utilities. Available on reasonable notice. Northwest preferred. B-9078.

ELECTRICAL ENGINEER, technical education, past five years with the electrical engineering departments of large public utilities. Qualified to handle all relay and protection problems, successful record in handling and organizing designing or drafting organizations. Three years' experience valuation and appraisal work. B-9079.

ELECTRICAL ENGINEER, technical graduate, desires connection with engineering firm, public utility, mine or exporter. Twelve years' experience public utility, manufacturing, foreign sales heavy machinery, power utilization in mining, metallurgy, crushing, pumping, etc. Fluent Spanish, French. Available January 1st. B-9074.

MECHANICAL AND ELECTRICAL ENGINEER, with executive and commercial experience. Familiar power plants, factory maintenance, electrical transmission, distribution and motor applications. Location, New York district. Now employed. B-8448.

M. I. T. GRADUATE, S. B. in electrochemical engineering 1922, and S. M. (no course but taken in electrical engineering department specializing in electrical engineering, physics, radio, chemistry, mathematics), 1924. Desires teaching opportunity at educational institution in specialties. Interested in higher study and research. Location dependent on opportunity. Available now. B-8380.

ELECTRICAL ENGINEER, technical education, experienced in the design of polyphase induction and direct current motors. Desires position with an electrical motor manufacturing company as motor designer. Twenty-four years' experience in designing and development of alternating and direct current motors, investigation, service work, electrical construction and maintenance. B-9016.

GRADUATE ELECTRICAL ENGINEER, age 26. Two years' experience on lighting and control circuits, eighteen months on General Electric Test and six months' general office experience in the same company, also six months electrical inspection work. Will be available on one week's notice. B-9090.

STUDENT A. I. E. E., technical training, age 28, would like to start with some power company in a substation or on construction. Have some construction experience, also experience as a machinist. B-9084.

ELECTRICAL ENGINEER, technical graduate, age 29, desires to make connections with engineering firm, consulting engineers or architects. Experience as follows: five years electrical construction, two years as inspector, two years specification writing, one year of sales. Willing to travel. Available at two weeks' notice. B-5431.

INDUSTRIAL ELECTRICAL ENGINEER, experienced in design and manufacture of electric household devices, ranges, vacuum bottles, cleaners and small motors. Five years with present employers. Now in charge electrical test and development, ten million dollar concern. Ten years in field, one and one half years in large electrical laboratory, balance manufacture. Wishes change to progressive concern with broader opportunities. Age 28, married. Available thirty days. B-9082.

RECENT GRADUATE, B. S. in E. E. from M. I. T. 1924, age 21. Desires position as a student engineer, preferably with a public utility, but would consider sales engineering. Location desired New England, or Eastern States. B-8516.

ELECTRICAL ENGINEER, technical graduate, age 29, four years with G. E. Company testing and engineering, five years with anthracite coal company, engineering, installation, testing, etc. Familiar with all phases of electrical applications as applied to mining. B-6878.

GRADUATE ELECTRICAL ENGINEER with wide experience in installation, operation and maintenance of electrical and mechanical equipment in coal and metal mining and industrial plants. Desires responsible position as chief electrician or superintendent power and mechanical department with large operation. Minimum salary $3600. Available reasonable notice. Age 35, married. B-9113.

TECHNICAL GRADUATE, experienced in design, costs, manufacture, testing and research of low and high tension underground transmission and distribution cables. Desires position along similar lines with either a manufacturer of cable, or a reliable consulting engineer. Interested only in a permanent position offering opportunity. Available on one month's notice. B-9120.

GRADUATE ELECTRICAL ENGINEER 1923, B. S. in E. E., interested in experimenting and research, through knowledge of radio receiving sets, several years' experience in electrical drafting and design, mathematician, inventive ability, desires connection with radio or electrical firm. Prepared to put forth every intelligent effort in the interest of firm. Minimum salary $2100. B-7332.

TECHNICAL GRADUATE, E. E. training, 25, married, desires responsible permanent position electrical concern, production, installation or radio development. Experience over four years inspection and installation of electrical equipment. Location one hundred miles or less from New York City. Available reasonable notice. References on request. Salary $2600. B-9117.

ELECTRICAL ENGINEER, age 39, broad experience supervising designs, construction and operation of power, substations and industrial plants, transmission and distribution systems, lighting, power, telephone and telegraph layouts, electrolysis surveys, making up reports, rates, appraisals and specifications. Member A. I. E. E., Member I. E. S., etc. B-3954.

ELECTRICAL GRADUATE with eleven years' experience installation and maintenance of mechanical and electrical equipment in industrial plant. Installation of powerhouse and substation equipment. Would like position as plant engineer or similar position. Age 30. B-9114.

ASSISTANT EXECUTIVE, technical graduate, 33, married. Desires connection with progressive company in commercial capacity, or industrial engineering firm. Work has covered manufacturing, time studies, plant layout, distribution systems, costs, sales, advertising and statistical studies of expenses, revenues and other administrative problems. Location, New York. New England. Available reasonable notice, B-9122.

GENERAL SUPERINTENDENT, available February first, technical education and factory experience plus sixteen years' experience in construction, maintenance and operating hydro and steam power systems and large transmission net works at high voltage. Have paid particular attention to maintaining service, organization and development and have combined the duties of an executive, engineer and superintendent. Now employed but would like a place on a system where considerable changes, additions, etc., are taking place. B-9126.

GRADUATE ELECTRICAL ENGINEER, 28, single, '23 graduate. Experience covers sales and design. Desires position at factory leading to a sales position. Now available. Location, Central States or East. B-7239.

POWER PLANT ENGINEER, age 25, married, B. S. in E. E. in 1921. One year general test work with large manufacturer, two and one half years supervising steam research and water rate work. Desires a connection with both steam and electrical work leading to power plant engineering. References obtainable from present employer. Minimum salary $3000. B-9125.

GRADUATE ELECTRICAL ENGINEER, 35, desires position of responsibility with engineering firm, utility, or as representative of non-technical institution. Broad engineering and business experience as executive, includes determination of designs for power plants, lines, factories, etc., selection of materials and equipment, construction, supervision, investigations of rates, development and financing. B-8237.

GRADUATE ELECTRICAL ENGINEER, age 24, six months motor test, fourteen months construction work of transformers, desires permanent responsible position. Am young and can learn your methods. Available on short notice. B-8990.

ELECTRICAL AND MECHANICAL ENGINEER fully qualified, is visiting the United States in February next and is desirous of representing in Australia reliable firms of electrical manufacturers in the following lines: motors, switchgear, cables, telephones and telephone accessories, lighting supplies and wireless equipment. B-9139.

GRADUATE ELECTRICAL ENGINEER, age 26, single. Two years' experience on lighting and control circuits, eighteen months on General Electric Company Test, six months' general office experience in the same company, also six months electrical inspection work. Available on one weeks' notice. Location, East. B-9090.

MECHANICAL AND ELECTRICAL ENGINEER, 34, married, extensive experience in design and operation of power stations, substations for railway and power, industrial plants, railway shops, process steam, etc. Wishes connection with engineers, manufacturing plant or growing public utility. Available January 1st. Location, Eastern States. B-6852.

ELECTRICAL-MECHANICAL ENGINEER, graduate of Royal Turin's Polytechnic (Italy), age 28, single. Initiative and inventive ability; testing laboratory experience, substation operation practice, good draftsman. Desires position with reliable concern, also radio line. Knowledge of French, Italian. Willing to start on manual work. Location anywhere, New York City preferred. B-7208.

ELECTRICAL ENGINEER, age 25, single, four years with large public utility in laboratories making trouble investigations in factories and compiling reports. Desires position as service engineer for electrical manufacturer, sales engineer or in engineering department of private concern. Familiar with Philadelphia and vicinity. Location, Philadelphia or New York City. B-6670.

CHIEF ELECTRICIAN OR FOREMAN, ten years' experience, five years U. S. Navy, married, age 30. One year and nine months Westinghouse Service Department, N. Y. C., power plant construction, marine, house and factory work. Switchboard wiring and small wiring a specialty. Had executive experience. B-9173

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES REELECTED DECEMBER 5, 1924

AKER, WILLIAM ALLISON, Equipment Man, Equipment Dept., Western Union Telegraph Co., Atlanta, Ga.

*AMEZAGA, MIGUEL FERNANDO, Asst. Engineer, The Francisco Sugar Co., Francisco, Prov. de Camaguey, Cuba.

ANTRACK, HENRY, Mechanic, R. Hoe & Co., Grand & Sheriff Sts., New York, N. Y.

APIKIAN, GIZ, Draftsman, Engineering Dept., New York Edison Co., 44 E. 23rd St., New York, N. Y.

ARAI, KOH-ICHI, Electrical Engineer, Mitsubishi Electrical Engineering Co., Kobe, Japan.

BARRINGTON, FREDERICK HERBERT, Chief Electrical Engineer, Moloney Electric Co., St. Louis, Mo.

BECK, ALBERT W., Electrician, Kentucky Utilities, Pineville, Ky.; for mail, Tompkinsville, N. Y.

BIBERMAN, LOUIS S., Electrical Draftsman, Switchboard Dept., General Electric Co., Schenectady, N. Y.

BOOTH, RALPH DOUGLAS, Electrical Engineer, Jackson & Moreland, 31 St. James Ave., Boston, Mass.

*BROWN, JESSE EDWARD, Asst. U. S. Radio Inspector, Detroit, Mich.; res., East Marion, N. Y.

*BUENAFE, MAMERTO M., Electrical Meter Tester, Livingston Power House, Staten Island Edison Co., Staten Island, N. Y.

CARSON, ANDREW HOWARD, Asst. Telegraph Engineer, Posts & Telegraphs Dept., Kuala Lumpur, Federated Malay States.

CARSWELL, DAVID M., Engineer in Charge of Requisitions Switchboard Dept., General Electric Co., Schenectady, N. Y.
CIPOLLETTI, C. T., Tester, General Electric Co., Bloomfield; res., Newark, N. J.
CLARKE, DENNIS IVER, Asst. Engineer, British Columbia Electric Railway Co., Vancouver, B. C., Can.
COFFIN, JOHN RUSKIN, Engineer, Jackson & Moreland, 31 St. James Ave., Boston; res., West Medford, Mass.
CUMMER, ROBERT LOCKMAN, Manufacturer, Canadian Line Materials, Ltd., Toronto, Ont., Can.
DAVIDSON, MAXWELL, S., Chief Engineer, Western Steel Products Co., 1401 Osage St., Denver; res., Rocky Ford, Colo.
DAVIS, CARLTON C., Receiving & Broadcasting Operator, Radio Corp. of America, 33 W. 42nd St., New York; res., Brooklyn, N. Y.
DEACON, HARRY L., Jr., Inspector, Westinghouse Elec. & Mfg. Co., 12 Farnsworth St., Boston; res., Somerville, Mass.
DELEHANTY, JAMES EVERETT, Engineering Dept., General Electric Co., 814 Rialto Bldg., San Francisco, Calif.
*DIFFENDAFFER, JOSEPH ALEXANDER, Auto. Electrician & Battery Repair Man, Holtzschue Motor Co., 216-17 W. Main, Norman, Okla.
*EHRLICH, MAX, Draftsman, New York Rapid Transit Corp., 85 Clinton St., Brooklyn, N. Y.
ELDOEN, SVEIN, Electrician, West Penn Power Co., Freeport, Pa.
EVANS, CLIVE WALTER, Electrical Engineer, Waratah, Tasmania; for mail, Brighton, Melbourne, Australia
FARDOE, HARRY RICHARD, Asst. Electrical Engineer, Moloney Electric Co. of Can., 213 Sterling Rd., Toronto, Ont., Can.
FINKE, AUGUST B., Draughtsman, New York Edison Co., 130 East 15th St., New York, N. Y.
FISCHER, CHARLES A., Electrical Designer, Dwight P. Robinson & Co., Inc., 125 E. 46th St., New York, N. Y.; for mail, Pittsburgh, Pa.
FLYNN, WILLIAM BURWELL, Electrical Engineer, Day & Zimmerman, 1600 Walnut St., Philadelphia, Pa.
FRAPWELL, HERBERT L., Resident Engineer, Research Corp., Bound Brook; res., Elizabeth, N. J.
*FRETZ, JOHN CLEMENT, Student, Testing Dept., General Electric Co., Schenectady, N. Y.
*GARRETT, PERCY B., General Engineer, Westinghouse Elec. & Mfg. Co., 1st National Bank Bldg., San Francisco, Calif.
GEESAMAN, JOHN ELMORE, Jr., Electrical Contractor, 104 East Orange St., Shippensburg, Pa.
GHIOKAS, ARISTEDES, Special Tester, Laboratory & Testing Div., Philadelphia Electric Co., 2301 Market St., Philadelphia, Pa.
GILL, PETER CLARK, Distribution Engineer, British Columbia Electric Railway Co., Vancouver, B. C., Can.
GOOD, LOUIS, Jr., Meter Dept., Union Electric Light & Power Co., 414 N. 10th St., St. Louis, Mo.
HAHN, OTTO H., Electrical Engineer, Siemens (S. A.) Ltd., Johannesburg, South Africa.
HALL, EDWARD HARVEY, Switchboard Engg. Dept., General Electric Co., Schenectady, N. Y.
HAMMERSLEY, THOMAS L., Treasurer, Goodyear & Hammersley, Inc., 30 Church St., New York, N. Y.
HANSON, EDWARD CREIGHTON, Student, Dixville, P. Q., Can.
HASSAN, BAHIG, Morkrum Co., 1410 Wrightwood Ave., Chicago, Ill.
*HAVENHILL, MARSHALL A., Industrial Control Engineer, General Electric Co., Schenectady, N. Y.
HOLDER, DEWITT HERNDON, Jr., Electric Meterman, Oklahoma Gas & Electric Co., Drumright, Okla.
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MESERVE, RALPH HAROLD, Results Man, Hill Station, St. Paul Gas Light Co., St. Paul, Minn.
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PARKER, RAYMOND WHITFIELD, Asst. Engineer, Sydney E. Junkins Co., Ltd., 614 Metropolitan Bldg., Vancouver, B. C., Can.
PARRY, WILLIAM, Transformer Engineer, The English Electric Co., Ltd., Siemens Works, Stafford, England.
*PORTER, WILLIAM ASBURY, Switchboard Attendent, Public Service Co. of Colorado, Glenwood Springs; res., Denver, Colo.
PORTIS, ROBERT J., Asst. Engineer, City National Bank Bldg., Pacific South West Bank Bldg., Long Beach, Calif.
RANDALL, HARRY A., Field Engineer, Duquesne Light Co., Chamber of Commerce Bldg., Pittsburgh, Pa.
RANKIN, CARL SEIB, Asst. Professor in Civil & Electrical Engineering, University of Delaware, Newark, Del.
RARICK, JOSEPH CONAN, Substation Operator, Cleveland Electric Illuminating Co., Illuminating Bldg., Cleveland, Ohio.
ROSENKRANZ, JOSEPH A., President & General Manager, National Automotive School & National Elec. & Engg. School, 4006 S. Figueroa St., Los Angeles, Calif.
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SANTOS, BERNARDINO, Rio Piedras, Porto Rico.
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SHEPHERD, BLAND V., District Meter Tester & Inspector, Iowa Service Co., 300 E. Erie St., Missouri Valley, Iowa.
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STANGEBY, S. A., Construction Foreman, Adirondack Power & Light Corp., Schenectady; res., Glens Falls, N. Y.
*STARK, IRWIN A., Inspector, Brooklyn Edison Co., Hudson Ave. & John St., Brooklyn, N. Y.
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TAKAHASHI, MASAKAZU, Electrical Engineer, Electrotechnical Laboratory, Ministry of Communications, Tokyo, Japan.
TIKUMA, TYOZO, Electrical Designer, Shibaura Engineering Works, Tokyo, Japan.
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TYZZER, FRANKLIN GOWEN, 175 Water St., Wakefield, Mass.
UGALDE, JOSE I., General Foreman, Overhead Lines, Mexican Light & Power Co., Apartado 490, Mexico, D. F., Mex.
UPHAM, EVERETT LUTHER, Electrician, Barber-Colman Co., Rockford, Ill.
VALENT, ANDREW JOHN, Draftsman, O. S. Leszay, 15 Park Row, New York, N. Y.
VAN NIEKERK, ADRIANUS, Hotel Madison, 27th St. & Madison Ave., New York, N. Y.
VIGLIANO, JOSEPH, Electrical Designer, Electric Bond & Share Co., 71 Broadway, New York, N. Y.
VOLCKMANN, ERNST, Electrical Tester, Motive Power Dept., Interborough Rapid Transit Co., 600 West 59th St., New York, N. Y.; res., Bloomfield, N. J.
WALTZ, WILLIAM WILSON, Instrument Shop Western Electric Co., Inc., 11th & York Sts., Philadelphia, Pa.
WIGAN, LEONARD J. C., Adelaide Electric Supply Co., Ltd., Adelaide, So. Australia; for mail, London E. C. 2, England.
WORINGER, MALCOLM, 231 West 22nd St., New York, N. Y.
*WYETH, FRANCIS HOUSTON, Engineering Sales, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.
YOUNG, SAMUEL ALFRED, Asst. Engineer, British Columbia Electric Railway Co., 425 Carrall St., Vancouver, B. C., Can.

Total 100

*Formerly Enrolled Students

ASSOCIATES REELECTED DECEMBER 5, 1924

DIEDERICH, PETER, Superintendent, Light & Water Dept., City of Glendale, Glendale, Calif.

MILLIKEN, HUMPHREYS, Engineer, East Florence, Ala.

MEMBER REELECTED DECEMBER 5, 1924

VREELAND, FRANK PECK, Service Dept., Westinghouse Elec. & Mfg. Co., 10th Ave. & 36th St., New York, N. Y.; for mail, Jersey City, N. J.

MEMBERS ELECTED DECEMBER 5, 1924

FERGUSON, JOHN DAVIS, Asst. Engineer, Engg. Branch, Ministry of Posts & Telegraphs, Leitrim House, Dublin Castle, Irish Free State

ROSS, TASCAR ALAN, Consulting Engineer, Guaranty Trust Co., 140 Broadway, New York, N. Y.

TRANSFERRED TO GRADE OF MEMBER DECEMBER 5, 1924

BROWN, CLAUDE C., Gas & Electric Engineer, California Railroad Commission, Los Angeles, Calif.

CAMPBELL, ALLAN B., Electrical Engineer, National Electric Light Association, New York, N. Y.

CONLEY, BROOKS L., Electrical Engineer, The Hoover Company, North Canton, Ohio.

PARKER, KARR, Engineering Manager, McCarthy Brothers & Ford, Buffalo, N. Y.

ST. CLAIR, B. W., Engineer, Standardizing Laboratory, General Electric Co., West Lynn, Mass.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held December 1, 1924, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

MORROW, L. W. W., Associate Editor, Electrical World, New York.

ROBINSON, LLOYD N., Electrical Engineer, Stone & Webster Inc., Seattle, Wash.

PEEK, FRANK W., Jr., Consulting Engineer, General Electric Co., Pittsfield, Mass.

To Grade of Member

BAUM, HARRY, Ass't. Professor of Electrical Engineering, College of the City of New York, New York.

CHATFIELD, CLARENCE E., Sales Engineer, W. D. Hamer Co., Indianapolis, Ind.

CLEMENT, MILLARD F., Manager, Orange County Public Service Co. Inc., Middletown, N. Y.

ELLIOTT, HAROLD F., Consulting Engineer, Federal Telegraph Co. of Delaware, San Francisco, Calif.

FREED, JOSEPH D. R., President and Chief Engineer, Freed-Eisemann Radio Corp., New York, N. Y.

HOWARD, HENRY GEORGE, Chief Engineer, Cia Chilena de Electricidad, Santiago, Chile.

MERTENS, B. De M., Assistant Electrical Superintendent, B. C. Electric Railway Co., Vancouver, B. C.

NIESSE, JOHN L., Tel. & Tel. Engineer, New York Central Lines, New York.

OESTERREICH, EDMUND W., Superintendent, Underground Lines, Duquesne Light o., Pittsburgh, Pa.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before January 31, 1925.

Adams, C. F., University of Washington, Seattle, Wash.

Albach, H. J., Western Union Tel. Co., Butte, Mont.

Albaugh, A., Consolidated Gas, Elec. Light & Power Co., Baltimore, Md.

Alger, P. B., Boston Edison Laboratory, Boston, Mass.

Ames, W. C., Jr., Mass. Institute of Technology, Cambridge, Mass.

Anderson, D., Elec. Engr., H. S. Taylor, Montreal, Que., Can.

Anderson, G. H., (Member), General Electric Co., Springfield, Mass.

Andrich, J., U. S. Reclamation Service, Pilot, Wyoming

Appleby, H. A., A. T. & S. F. Railway, La Junta, Colo.

Atterling, K. G., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Avery, S. H., General Electric Co., Schenectady, N. Y.

Bach, L., Draftsman, 312 E. 8th St., New York, N. Y.

Bair, R. S., Western Electric Co., Inc., New York, N. Y.

Baker, I. T., Consolidated Gas, Elec. Light & Power Co., Baltimore, Md.

Baldwin, M. J., General Electric Co., Pittsfield, Mass.

Bardsley, C. E., Bardsley-Riley Electric Co., Newport, R. I.

Barrell, R. W., Jr., General Electric Co., Erie, Pa.

Barrows, K. C., Midwest Power Co., Devils Lake, N. Dak.

Barstow, W. A., (Member), Navy Yard, Mare Island, Calif.
(Applicant for re-election.)

Bartels, D., Canadian General Electric Co., Vancouver, B. C.

Bauer, J. A., Western Electric Co., Inc., New York, N. Y.

Beckert, E. H., General Electric Co., Schenectady, N. Y.

Belfry, R. S., Northern Electric Co., Ltd., Toronto, Ont., Can.

Bellinger, F. W., Butte, Anaconda & Pacific Ry. Co., Anaconda, Mont.

Bement, D. L., No. Indiana Gas & Electric Co., Hammond, Ind.

Benedict, S. D., (Member), N. Y. State Dept. of Architecture, Albany, N. Y.

Bennett, L. M., The Cleveland Railway Co., Cleveland, Ohio

Benson, W. R., Bell Tel. Co. of Canada, Toronto, Ont., Can.

Bentley, W. H., Dept. of Telephones, Regina, Sask., Can.

Bergstraser, E. J., Murrie & Co., New York, N. Y.

Betts, P. H., Western Electric Co., Inc., New York, N. Y.

Bjornson, B. G., Western Electric Co., Inc., New York, N. Y.

Blomquist, H. R., Stone & Webster, Inc., Boston, Mass.

Boorujy, G., Electrical Contractor, Summit, N. J.

Borokhovich, J. A., Brooklyn Edison Co., Brooklyn, N. Y.

Bossert, J. L., Stevens & Wood, New York, N. Y.

Bounce, P. R., Westinghouse Elec. & Mfg. Co., Sharon, Pa.

Bowker, E. I., Milwaukee Elec. Rwy. & Lt. Co., Milwaukee, Wis.

Briggs, W. N., General Electric Co., Pittsfield, Mass.

Bronson, G. A., General Electric Co., Erie, Pa.

Brown, B. N., Electrical Testing Laboratories, New York, N. Y.

Brown, H. D., General Electric Co., Schenectady, N. Y.

Brown, H. J., General Electric Co., Schenectady, N. Y.

Brown, R. J., University of Toronto, Toronto, Ont., Can.

Brown, R. L., The New Departure Mfg. Co., Bristol, Conn.

Brownell, H. S., Birmingham Electric Co., Birmingham, Ala.

Brun, O., Jr., Century Electric Co., St. Louis, Mo.

Bruns, W. H., Otis Elevator Co., Yonkers, N. Y.

Bueche, H. S., Brooklyn Edison Co., Brooklyn, N. Y.

Burlingame, R. E., University of Minnesota, Minneapolis, Minn.

Butterworth, P. Y., Edison Elec. Ill. Co. of Boston, Boston, Mass.

Campkin, W. L., Saskatchewan Gov't. Telephones, Regina, Sask., Can.

Carey, C. E., (Member), Westinghouse Elec. & Mfg. Co., Seattle, Wash.

Carey, E. F., Dwight P. Robinson Co., Inc., Pittsburgh, Pa.

Carey, J. C., So. California Edison Co., Los Angeles, Calif.

Carl, W. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Caskey, J. F., Lehigh Valley Railroad, Bethlehem, Pa.

Cassell, W. L., National Carbon Co., Inc., Cleveland, Ohio

Caverley, L. C., Mass. Inst. of Technology, Cambridge, Mass.

Chatham, C. L., Public Service Electric & Gas Co., Paterson, N. J.

Chilberg, E. N., General Electric Co., Schenectady, N. Y.

Cholick, J. G., Oregon Inst. of Technology, Portland, Ore.

Christopher, P. C., General Electric Co., Seattle, Wash.

Clark, L. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Classen, W. H., with Holabird & Roche, Chicago, Ill.

Cleary, J. V., Third Avenue Railway Co. of New York, New York, N. Y.

Clement, N. F., Cleveland Union Terminals Co., Cleveland, Ohio

Cleveland, H. R., Student, Danville, Que., Can.

Cockburn, J. M., Canadian General Electric Co., Peterboro, Ont., Can.

Cody, M. F., Jr., Asst. Elec. Engr., Board of Education, Brooklyn, N. Y.

Coe, S. M., Jr., Emergency Engineering Co., Sterling, Ill.

Coleman, J. B., Radio Station WBZ, Springfield, Mass.

Colyer, H. J., Michigan Bell Tel. Co., Detroit, Mich.

Cone, J. H., West Penn Power Co., Pittsburgh, Pa.

Coneway, C. W., Purdue University, West Lafayette, Ind.

Connon, W. D., Bell Tel. Co. of Pa., Philadelphia, Pa.

Conner, G. W., Jr., Pomeroy's Inc., Reading, Pa.

Converse, C. M., St. Paul Electric Co., St. Paul, Minn.
(Applicant for re-election.)

Cook, J. E., Kansas City Power & Light Co., Kansas City, Mo.

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Costenoble, E. H., Philadelphia Electric Co., Philadelphia, Pa.

Cox, J. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Crago, A. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Cravens, R. C., Indiana Service Corp., Fort Wayne, Ind.

Crivy, A., Electrical Draftsman, City of New York, New York, N. Y.

Crofut, W., Brooklyn Edison Co., Brooklyn, N. Y.

Dahl, H. W., Electric Machinery Mfg. Co., Minneapolis, Minn.

Dani, A., American Tel. & Tel. Co., New York, N. Y.
Dania, G., New York Central R. R., New York, N. Y.
Davenport, T. L., Union Gas & Electric Co., Cincinnati, Ohio
Davidson, J., With State Engineer, Albany, N. Y.
Day, H. B., The Holtzer-Cabot Electric Co., New York, N. Y.
Dennis, O. H., Southwestern Bell Tel. Co., St. Louis, Mo.
Detlor, W. K., Bell Telephone Co. of Canada, Montreal, Que., Can.
De Turk, E. R. S., Westinghouse Elec. & Mfg Co., East Pittsburgh, Pa.
Devlin, R. V., General Electric Co., Erie, Pa.
Dhir, R. C., University of Wisconsin, Madison, Wis.
Diefenbach, L. T., Commonwealth Edison Co., Chicago, Ill.
Diehm, C., Electric Storage Battery Co., Philadelphia, Pa.
Domingues, L., General Electric Co., Schenectady, N. Y.
Doody, C., (Member), Saskatchewan Gov't. Telephones, Regina, Sask., Can.
Dormer, W. J. S., Bell Telephone Co. of Canada, Montreal, Que., Can.
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Einhart, H., General Electric Co., Schenectady, N. Y.
Eitman, J. F., General Electric Co., Fort Wayne, Ind.
Elder, C. T., Cleveland Electric Illuminating Co., Cleveland, Ohio
Ellis, E., Ohio Power Co., Newark, Ohio
Ellis, W. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
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Findley, R. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Fisher, L. W., Public Service Co. of No. Illinois, Evanston, Ill.
Fleming, H. F., Philadelphia Electric Co., Philadelphia, Pa.
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Freeman, C. E., York Haven Water & Power Co., York Haven, Pa.
Freericks, B., Jr., Freed-Eiseman Radio Corp., Brooklyn, N. Y.
Frey, A. P., United Railways & Electric Co., Baltimore, Md.
Friedmann, L., New York Edison Co., New York, N. Y.
Fry, J. R., (Member), Western Electric Co., Inc., New York, N. Y.
Fudge, L., General Electric Co., Seattle, Wash.
Fuller, H. E., Duquesne Light Co., Pittsburgh, Pa.
Gafford, B. N., University of Texas, Austin, Texas
Gale, R. E., Idaho Power Co., Boise, Idaho
Gallager, J. B., Philadelphia Electric Co., Chester, Pa.
Gannon, J. J., Philadelphia Electric Co., Philadelphia, Pa.
Garrett, R. A., Consumers Power Co., Jackson, Mich.
Garver, H. L., General Electric Co., Schenectady, N. Y.
Gates, H. S., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
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Grosser, G. E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Guida, T. J., Union Carbide & Carbon Res. Lab., Long Island City, N. Y.
Haedler, H., Best Foods, Inc., San Francisco, Calif.
Haggerty, J. J., Contractor, Scranton, Pa.
Hamil, J. W., The Dingle Clark Co., Cleveland, Ohio
Hanson, F. E., Western Electric Co., Inc., New York, N. Y.
Hardcastle, E., United Electric Light & Power Co., New York, N. Y.
Hardin, L. H., Mees & Mees, Charlotte, N. C. (Applicant for re-election).
Hardsog, H. N., Purdue University, West Lafayette, Ind.
Harris, L. K., General Electric Co., Schenectady, N. Y.
Harrison, M. E., Los Angeles Railway Corp., Los Angeles, Calif.
Hartman, H. W., General Electric Co., Schenectady, N. Y.
Hawkins, R. M., University of Toronto, Toronto, Ont., Can.
Healy, W. L., H. L., Cooper, U. S. Engineer Office, Wilson Dam, Ala.
Heath, E. B., General Electric Co., Schenectady, N. Y.
Hedrick, E. R., (Member), University of California, Los Angeles, Calif.
Heflin, N. M., Monongahela West Penn Public Service Co., Fairmont, W. Va.
Herbruck, W. M., Thomas-Smith Co., Canton, Ohio
Herlihy, J. A., Edison Electric Ill. Co. of Boston, Boston, Mass.
Hess, W. T., New Orleans Public Service, Inc., New Orleans, La.
Hickernell, L. F., Commonwealth Power Corp., Jackson, Mich.
Hirschel, L., Williamsburg Power Plant Corp., Brooklyn, N. Y.
Hoff, C. J. R., Edison Electric Ill. Co. of Boston, Boston, Mass.
Holroyd, A., (Member), Prudential Insurance Co., Newark, N. J.
Homan, C. W., Brooklyn Edison Co., Brooklyn, N. Y.
Hooper, R., The Kansas City Southern Railway Co., Kansas City, Mo.
Horn, H. J., Western Electric Co., Inc., Los Angeles, Calif.
Horne, J., New York Edison Co., New York, N. Y.
Hough, E. L., General Electric Co., Schenectady, N. Y.
Houser, K. O., General Electric Co., Pittsfield, Mass.
Howe, G. E., So. California Edison Co., Alhambra, Calif.
Howes, F. S., McGill University, Montreal, Que., Can.
Hubbard, F. A., Western Electric Co., Inc., New York, N. Y.
Hudack, J. M., Western Electric Co., Inc., New York, N. Y.
Hudson, H. L., General Electric Co., Seattle, Wash.
Hughes, E. T., Phoenix Utility Co., Hazleton, Pa.
Hunt, O. D., Kansas State Agricultural College, Manhattan, Kans.
Ilgenfritz, P., So. California Edison Co., Los Angeles, Calif.
Imburgia, C., American Gas & Electric Co., New York, N. Y.
Innes, F. R., Sessions Engineering Co., Chicago, Ill. (Applicant for re-election.)
Irving, E., Western Union Telegraph Co., New York, N. Y.
Isreal, D. D., Cleartone Radio Co., Cincinnati, Ohio
Jackson, R. R, Ohio Bell Telephone Co., Akron, Ohio
Jarvis, K. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Johns, F. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Johnson, A. L., Minerallac Electric Co., Chicago, Ill.
Johnson, E., Allis-Chalmers Mfg. Co., West Allis, Wis.
Johnson, G. H., Pacific Tel. & Tel. Co., San Francisco, Calif.
Johnston, A. M., The Steel Co. of Canada, Ltd., Hamilton, Ont., Can.
Jones, A. L., Ohio Bell Tel. Co., Cleveland, Ohio
Jones, B. L., (Member), Alabama Power Co., Birmingham, Ala.
Jones, E. R., University of Colorado, Boulder, Colo.
Jones, J. W., Western Electric Co., Inc., St. Louis, Mo.
Jones, T. B., Century Electric Co., St. Louis, Mo.
Joy, J. M., Connecticut Light & Power Co., Waterbury, Conn.
Juergens, W. A., Reliance Elec. & Engg. Co., Cincinnati, Ohio
Kahan, I. J., National Airphone Co., New York, N. Y.

Kahn, F., Philadelphia Electric Co., Philadelphia, Pa.
Kalem, J. C., Murrie Co., Inc., New York, N. Y.
Kamm, J. L., National Lamp Wks. of G. E. Co., Nela Park, Cleveland, Ohio
Katzman, J., Dubilier Condenser & Radio Corp., New York, N. Y.
Keely, C. D., Westinghouse Union Battery Co., North Bergen, N. J.
Keene, E. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Keener, J., Eldson Electric Co., Chicago, Ill.
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Kenner, A., Western Electric Co., Inc., New York, N. Y.
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Kent, H. E., National Electric Light Association, New York, N. Y.
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King, G. W., Commonwealth Power Corp., Jackson, Mich.
Kinney, E. A., Spooner & Merrill, Grand Rapids, Mich.
Kirkwood, R. V., Constr. Service, Quartermaster Corps, (U. S. A.) Washington, D. C.
Kohler, H. W., The Milwaukee Electric Railway & Lt. Co., Milwaukee, Wis.
Kressler, C. H., Penna. Power & Light Co., Allentown, Pa.
Kubiak, H. J., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Lamb, J. J., Lamb Bros., Michigan, N. Dak.
Lancaster, E. F., General Electric Fan Motor Co., Pittsfield, Mass.
Lane, R. B., General Electric Co., Schenectady, N. Y.
Lang, G. F., Public Service Co. of Colorado, Boulder, Colo.
Larter, W. D., Saskatchewan Gov't. Telephones, Regina, Sask., Can.
Lawrence, F. P., Southwestern Bell Tel. Co., St. Louis, Mo.
Lawton, F. L., General Electric Co., Schenectady, N. Y.
Leach, T., Saskatchewan Gov't. Telephones, Regina, Sask., Can.
Lear, W. H., American Tel. & Tel. Co., New York, N. Y.
Learned, E. D., Worcester Electric Light Co., Worcester, Mass.
Lee, J. A., United States Reclamation Service, Pavillion, Wyo.
Leeson, J. H., Dept. of Telephones, Regina, Sask., Can.
Leggett, J. A., Westinghouse Elec. & Mfg. Co., Boston, Mass.
Lehmann, C. H., New York Telephone Co., New York, N. Y.
Leonarz, E., Jr., Instructor of Elec. Engg., Mexico City, Mex.
Lerch, R. T., 216 Burke St., Easton, Pa.
Lieberman, H., Tri-State Tel. & Tel. Co., St. Paul, Minn.
Lindley, J. R., C. F. Pease Co., Chicago, Ill.
Listmann, C. W., Bureau of Pr. & Lt., City of Los Angeles, Los Angeles, Calif.
Little, L. C., Patent Office, Washington, D. C.
Lloyd, F. D., General Railway Signal Co., Rochester, N. Y.
Longley, F. R., General Electric Co., Schenectady, N. Y.
Loria, D. J., Public Service Production Co., Newark, N. J.
Loughery, G. B., Jr., Bell Telephone Co. of Pa., Philadelphia, Pa.
Loukianoss, G. M., General Electric Co., Pittsfield, Mass.
Love, N. R., E. Stenger, Denver, Colo.
Loveland, H. A., Binghamton Light, Heat & Power Co., Johnson City, N. Y.
Luecke, T. E., M. W, P. P. S. Co., Parkersburg, W. Va.
Lyman, W. J., Duquesne Light Co., Pittsburgh, Pa.
Lynch, C. B., General Electric Co., Schenectady, N. Y.
MacDonald, R. A., Salt River Valley Users Ass'n., Phoenix, Ariz.
Maier, O. T., New Orleans Public Service, Inc., New Orleans, La.
Maleckar, W. R., Aluminum Co. of America, Minneapolis, Minn.
Maltby, C. L., Public Service Co. of Illinois, Chicago, Ill.
Manion, W. J., Southwestern Bell Tel. Co., St. Louis, Mo.
Manning, J. B., Puget Sound Power & Light Co., Kelso, Wash.
Mansfield, C. G., General Electric Co., Pittsfield, Mass.
Marcellus, F. S., General Electric Co., Schenectady, N. Y.
Marchese, V. J., Freed-Eisemann Radio Corp., Brooklyn, N. Y.
Marlow, V. H., National Electrical School, Los Angeles, Calif.
Marsh, E. S., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Marthens, A. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Maslin, A. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Mason, A. F., Northwestern Bell Telephone Co., Omaha, Nebr.
Mason, E. C., Puget Sound Navy Yard, Bremerton, Wash.
Matlin, I., Safety Insulated Wire & Cable Co., Bayonne, N. J.
Matsuo, K., Worcester Polytechnic Institute, Worcester, Mass.
Maust, C. I., United Gas Improvement Co., Philadelphia, Pa.
McAuley, P. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
McCoy, R. L., Locke Insulator Corp., Baltimore, Md.
McCracken, W. F., The Pacific Tel. & Tel. Co., Seattle, Wash.
McCullough, R. T., Long Island Lighting Co., Bay Shore, N. Y.
McDonald, J. W., Commonwealth Power Corp., Jackson, Mich.
McIlhenny, I. F., Panama Canal, Balboa Heights, C. Z.
McKay, J. W., Northern Electric Co., Toronto, Ont., Can.
McLean, G. E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Menzel, A. F., Freed-Eisemann Radio Corp. Brooklyn, N. Y.
Metzger, W. E., Westinghouse Elec. & Mfg. Co., Columbus, Ohio
Meurer, S. T., N. Y. & T. Electric Light & Power Co., Flushing, N. Y.
Meyer, H. F., Vacuum Oil Co., Bayonne, N. J.
Mier, C. W., Southwestern Bell Tel. Co., St. Louis, Mo.
Milburn, J. B., Duquesne Light Co., Cheswick, Pa.
Miller, H. E., Nat'l. Advisory Comm. for Aeronautics, Langley Field, Va.
Miller, J. I., St. Paul Gas Light Co., St. Paul, Minn.
Miller, W., Louisville Gas & Electric Co., Louisville, Ky.
Minnium, B. B., Walbert Mfg. Co., Chicago, Ill.
Misener, E. C., Polytechnic College of Engineering, Oakland. Calif.
Mitchell, G., Rutgers College, New Brunswick, N. J.
Montague, R. G., The Pacific Tel. & Tel. Co., Santa Cruz, Calif.
Monteith, A. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Moor, H. E., Bangor Railway & Electric Co., Bangor, Me.
Moore, L. S., Bell Telephone Co. of Canada, Montreal, Que., Can.
Moore, W. C., Dept. of Telephones, Moose Jaw, Sask., Can.
Moreno, G., Pacific Gas & Electric Co., San Francisco, Calif.
Morgan, G., Jr., Cornell University, Ithaca, N. Y.
Morss, P. R., Simplex Wire & Cable Co., Cambridge A, Mass.
Mowry, R. I., General Electric Co., Schenectady, N. Y.
Mucha, T., Duquesne Light Co., Wilkinsburg, Pa.
Muir, A. C., General Electric Co., Schenectady, N. Y.
Mullen, J. N., Cap Magdalen Pulp & Lumber Co., Ltd., Riviere Madeleine, Gaspe Co., Que., Can.
Murphy, J. K., Southern Railway System, Orange, Va.
Naegeli, F. A., Interboro Rapid Transit Co., New York, N. Y.
Nash, H. R., Detroit Edison Co., Detroit, Mich.
Nattress, D. I., Hydro-Elec. Power Comm. of Ontario, Niagara Falls, Ont., Can.
Nelson, F. S., A. T. & S. F. Ry., Topeka, Kansas
Neuman, L. J., University of Oregon, Eugene, Ore.
Newton, C. H., Westinghouse Elec. & Mfg. Co., Chicago, Ill.
Nimmcke, F. E., Brooklyn Edison Co., Brooklyn, N. Y.
Norton, E. L., Western Electric Co., Inc., New York, N. Y.
Nottingham, F. O., Jr., General Electric Co., Schenectady, N. Y.
Nowell, F. G., New York Electrical School, New York, N. Y.
Nye, J. F., Westerly Light & Power Co., Westerly, R. I.
O'Dair, E. F., General Electric Co., New York, N. Y.
O'Driscoll, G. C., Consolidated Gas Co., Astoria, N. Y.
Oesper, E. W., Jr., Union Gas & Electric Co., Cincinnati, Ohio
Olds, R. N., Commonwealth Power Co., Jackson, Mich.
Olin, H., Minnesota Power & Light Co., Duluth, Minn.
O'Neil, H. T., Western Electric Co., Inc., New York, N. Y.
O'Neill, O., United Electric Light & Power Co., New York, N. Y.
Pabst, W., Brooklyn Technical High School, Brooklyn, N. Y.
Pannabaker, J. J., Vanadium Corp. of America, Bridgeville, Pa.
Papazian, N., Western Electric Co., Inc., New York, N. Y.
Parker, S. R., S. Edw. Eaton & Co., New York, N. Y.
Parrack, V. R., West Penn Power Co., Pittsburgh, Pa.
Patisteas, M. J. N., Stone & Webster, Inc., Boston, Mass.
Paxson, H. R., Philadelphia Electric Co., Philadelphia, Pa.
Pearlmutter, H. J., French & Hubbard, Boston, Mass.
Peirson, D. H., Philadelphia Electric Co., Philadelphia, Pa.
Pettengill, J. B., New York Edison Co., New York, N. Y.
Pew, R. K., Dodge's Inst. of Technology, Valparaiso, Ind.
Phelps, G. O., General Electric Co., West Lynn, Mass.
Powell, A. P., 530 Cambridge St., Allston, Boston, Mass.
Powers, L. W., United Electric Light & Power Co., New York, N. Y.
Pretz, J. C., Lehigh Portland Cement Co., Allentown, Pa.
Price, J. P., Stanford University; for mail, Oakland, Calif.
Price, L. D., Public Service Electric & Gas Co., Paterson, N. J.

Pritchard, E. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Rabke, R. F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ramsden, C. W., Safety Insulated Wire & Cable Co., Bayonne, N. J.
Raymond, H. N., General Electric Co., Salt Lake City, Utah
Redpath, A. J., General Electric Co., Erie, Pa.
Reed, R. O., Portland Electric Power Co., Portland, Ore.
Reinhardt, J. P., Electrical Contractor, Rosebank, S. I., N. Y.
Renner, L. N., Northern Ohio Traction & Light Co., Akron, Ohio
Rettenmeyer, F. X., Western Electric Co., Inc., New York, N. Y.
Rhine, F. P., Detroit Edison Co., Detroit, Mich.
Rich, W. C., Philadelphia Electric Co., Philadelphia, Pa.
Rider, P. N., Western Electric Co., Cleveland, Ohio
Riley, C. F., Western Electric Co., Inc., New York, N. Y.
Rivera, N. M., International General Electric Co., Schenectady, N. Y.
Robertson, R. R., (Member), Bureau of Power & Light, Los Angeles, Calif.
Robinson, H. B., Brooklyn Edison Co., Brooklyn, N. Y.
Rodnite, J. J., Murrie & Co., New York, N. Y.
Roesch, R. E., Phoenix Utility Co., Cienguegos, Cuba
Rogal, E., Morgan's, Inc., Roxbury, Mass.
Rohrdanz, E. C., Richmond Safety Gate Co., Chicago, Ill.
Ronningen, A., Western Electric Co., Inc., Chicago, Ill.
Rose, E. B., Northern Ohio Traction & Light Co., Akron, Ohio
Rosenberg, B., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Ross, G. O., Perry High School, Perry, N. Y.
Ross, M. V., Brown Corp., La Tuque, P. Q., Can.
Rossi, A. F., Jefferson Vocational School, St. Louis, Mo.
Rothschild, M., Rossiter, Tyler & McDonell, Inc., New York, N. Y.
Rotty, O. J., Union Electric Light & Power Co., St. Louis, Mo.
Rue, E. C., Edison Elec. Illiminating Co. of Boston, Boston 10, Mass.
Ruess, C. N., Bureau of Power & Light, Los Angeles, Calif.
Ruff, J. W., Charleston Consolidated Rwy. & Ltg. Co., Charleston, S. C.
Rufsvold, A. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ryder, F., Canadian Co-operative Wheat Producers, Ltd., Ft. William, Ont., Can.
Salneu, G. C., Philadelphia Electric Co., Philadelphia, Pa.
Sanbe, N. C., Philadelphia Electric Co., Chester, Pa.
Schaefer, J. P., General Electric Co., Schenectady, N. Y.
Schaeffer, E. R., Johns-Manville, Inc., New York, N. Y.
Schei, I., Dwight P. Robinson & Co.. Pittsburgh, Pa.
Schmalmaack, C. L., Georgia Railway & Power Co., Atlanta, Ga.
Schmitz, R. C., General Electric Co., Pittsfield, Mass.
Schonborn, R. J., City of Los Angeles, Bureau of Pr. & Lt., Los Angeles, Calif.
Schotter, G. J., U. S. Patent Office, Washington, D. C.
Schray, R. R., Akron Motor & Generator Repair Co., Akron, Ohio
Schuch, L. S., Westinghouse Elec. & Mfg. Co., Denver, Colo.
Schumacher, H. A., New York Edison Co., New York, N. Y.
Schump, R. R., Commonwealth Edison Co., Chicago, Ill.
Scott, J. A., Mass. Institute of Technology, Cambridge, Mass.
Scott, W. M., New York Edison Co., Brooklyn, N. Y.
Sealey, W. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
See, W. H., General Electric Co., Schenectady, N. Y.
Seitz, V., Cleveland Clinic, Cleveland, Ohio
Selleck, H. G., The Connecticut Power Co., Middletown, Conn.
Selquist, R., Copperweld Steel Co., New York, N. Y.
Sessions, A. P., Southern California Edison Co., Los Angeles, Calif.
Sharp, H., Mountain States Tel. & Tel. Co., Denver, Colo.
Shea, H. G., Puget Sound Power & Light Co., Seattle, Wash.
Sherman, R. E., Public Service Electric Co., Elizabeth, N. J.
Shermer, F. C., Philadelphia Suburban Gas & Elec. Co., Wyncote, Pa.
Shew, E. B., Philadelphia Electric Co., Philadelphia, Pa.
Shields, S., Canadian General Electric Co., Peterboro, Ont.,Can.
Shockley, H. M., Canadian General Electric Co., Peterboro, Ont., Can.
Shorey, G. H., Jr., General Electric Co., Schenectady, N. Y.
Signeul, R., Stone & Webster, Inc., Boston, Mass.
Singleton, B., Canadian General Electric Co., Ltd., Toronto, Ont.
Siniapkin, N. M., State Dept. of Architecture, Albany, N. Y.
Skarolid, C. T., N. W. Bell Tel. Co., Minneapolis, Minn.
Sklar, Louis B., U. G. I. Contracting Co., Philadelphia, Pa.
Smith, F., Brooklyn Edison Co., Brooklyn, N. Y.
Smith, G. W., Vulcan Power Co., Netcong, N. J.
Smith, H. E., General Electric Co., Schenectady, N. Y.
Smith, W. E., Ward Leonard Electric Co., Mount Vernon, N. Y.
Snow, W. B., Stanford University, Stanford University, Calif.
Spafford, P. P., Texas Power & Light Co., Dallas, Texas
Spector, M., U. S. Patent Office, Washington, D. C.
Spencer, H. H., General Electric Co., Schenectady, N. Y.
Spethmann, G. E., Northwestern Bell Telephone Co., Sioux Falls, S. Dak.
Spilios, A. A., 291 Summit Ave., Allston, Mass.
Stebbins, F. O., General Electric Co., Schenectady, N. Y.
Steiner, J. L., New York Telephone Co., New York, N. Y.
Steinmetz, A. A., The Western Union Tel. Co., New York, N. Y.
Sussdorff, R. R., Sperry Gyroscope Co., Brooklyn, N. Y.
Stoll, A., School of Engg. of Milwaukee, Milwaukee, Wis.
Sweet, E. L., The Philadelphia Electric Co., Philadelphia, Pa.
Sykes, E. A., Montreal Light Heat & Power Cons., "Club House" Cedars, Que., Can.
Taylor, D. J., 88 Broad St., Boston, Mass.
Taylor, J. D., Northwestern Bell Tel. Co., Minneapolis, Minn.
(Applicant for re-election.)
Taylor, M. L., Brooklyn Edison Co., Brooklyn, N. Y.
Taylor, R. V., Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.
Taylor, W. T., So. California Telephone Co., Los Angeles, Calif.
Tennant, G. E., Syracuse Lighting Co., Syracuse, N. Y.
Tew, M. M., Bureau of Power & Light, Los Angeles, Calif.
Thayer, C. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Thomas, E. R., United Electric Light & Power Co., New York, N. Y.
Thompson, G. W., College of Elec. Engg. of Milwaukee, Milwaukee, Wis.
Thompson, J. H., New England Tel. & Tel. Co., Boston, Mass.
Tierney, W. H., General Electric Co., Seattle, Wash.
Timberlake, P. S., General Electric Co., Schenectady, N. Y.
Tomlinson, H. R., Fall River Electric Light Co., Fall River, Mass.
Topanelian, E., Jr., Worcester Polytechnic Inst., Worcester, Mass.
Torrens, T. M., New York Telephone Co., New York, N. Y.
Townsend, G. R., General Electric Co., Schenectady, N. Y.
Tranzen, K., Marshall Field & Co., Chicago, Ill.
Troop, C. R., New York Central Railroad, New York, N. Y.
Troster, M., Otis Elevator Co., Yonkers, N. Y.
Trow, L. S., Worcester City Hospital, Worcester, Mass.
Tsui, J. H. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Tunell, R. H., Western Electric Co., Inc., New York, N. Y.
Turk, P. C., General Electric Co., Schenectady, N. Y.
Turner, J. W., Dept. of Telephones, Regina, Sask., Can.
Turner, R. H., Dwight P. Robinson & Co., Providence, R. I.
Tyrrell, R. F., Brooklyn Edison Co., Brooklyn, N. Y.
Tuttle, E. L., Western Electric Co., Inc., Chicago, Ill.
Valentine, H. P., Puget Sound Power & Light Co., Bothell, Wash.
Van Pelt, E. V., Chesapeake & Potomac Tel. Co. of W. Va., Charleston, W. Va.
Van Iderstine, T. E., General Electric Co., Lynn, Mass.
Vascondelos, J. M., The Milwaukee Elec. Ry. & Lt. Co., Milwaukee, Wis.
Veith, H. E., National Electrical School, Los Angeles, Calif.
Vilett, E. W., Public Service Production Co., Newark, N. J.
Von Hoene, R. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Voronovsky, T. G., General Electric Co., Schenectady, N. Y.
Vouch, S. J., General Electric Co., Schenectady, N. Y.
Wagner, B. S., The Cincinnati & Suburban Bell Tel. Co., Cincinnati, Ohio
Walther, H., Western Electric Co., Inc., New York, N. Y.
Watts, H. O., The Sierras Power Co., Riverside, Calif.
Watts, T. R., Union Gas & Electric Co., Cincinnati, Ohio
Wear, E. G., Public Service Co. of No. Illinois, Joliet, Ill.
Weir, Alex, New York Central Railroad, New York, N. Y.
Wells, B. F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Werly, B. M., Eastman Kodak Co., Kodak Park, Rochester, N. Y.
West, F. P., United Electric Light & Power Co., New York, N. Y.
Wetton, N. H., Toronto Hydro-Electric System, Toronto, Ont.
White, Hazel M., Saskatchewan Gov't. Telephones, Regina, Sask., Can.
Wilkinson, H. B., Adirondack Power & Light Corp., Schenectady, N. Y.
Willhoft, F. O., (Member), T. H. Goldschmidt Corp., New York, N. Y.
Williams, A., Lord Electric Co., New York, N. Y.
Williams, J. C., Western Electric Co., Inc., Jersey City, N. J.
Williamson, T. A., Central Station Switchboard Operator, Waukegan, Ill.

Winter, P., American Smelting & Refining Co., Plant Maurer, N. J.
Witke, E. E., National Electrical School, Los Angeles, Calif.
Wolff, S., Roth Bros. & Co., Chicago, Ill.
Woodling, G. V., Pittsburgh & Lake Erie R. R., Beaver, Pa.
Woodrow, C. A., General Electric Co., Schenectady, N. Y.
Wright, S. B., American Tel. & Tel. Co., New York, N. Y.
Wundheiler, B. M., General Electric Co., Lynn, Mass.
Wyrtzen, C. C., Claude Neon Lights, Inc., New York, N. Y.
Yonezawa, M., Res. Rep. of Japanese Gov't. in U. S. A., New York, N. Y.
Younglove, G. W., General Electric Co., Nela Park, Cleveland, Ohio
Zimmerschied, C. R., Electric Machinery Mfg. Co., Minneapolis, Minn.
Total 505

Foreign

Copeland, J. B., J. B. Copeland & Co., San Jose, Costa Rica
Gabrielides, A. P., The English Electric Co., Preston, Lanc., Eng.
de Moraes, M. S. Acme-International Z-Ray Co., Rio de Janeiro, Brazil, S. A. (Applicant for re-election)
Kadlec, S., All America Cables, Inc., Mendoza, Argentine, S. A.
Kelkar, G. R., Victoria Jubilee Technical Institute, Matunga, Bombay, India
Komendantoff, D. A., Obukof Steel Shop, Obukowo, Leningrad, Russia
Noble, R., Jr., Porto Rico Ry., Lr. & Pr. Co., Comerio Falls, Bayomon, P. R.
Philippou, J. D., Poltyechnic Inst. of Leningrad, Lesnoi, Sosnovka, Leningrad, Russia
Rollo, W. S., (Member), Agr. College & Research Inst., Mandalay, S. Burma, India
Sims, W. D., Porto Rico Ry. Lt. & Pr. Co., Comerio, Bayomon, P. R.
Taylor, E. A., Turnbull & Jones, Ltd., Wellington, N. Z.
Wedderspoon, W. C., (Member), Carrick Wedderspoon, Christchurch, N. Z.
Whidden, W. H., Trinidad Consolidated Telephones, Ltd., Port of Spain, Trinidad, B. W. I.
Total 13

STUDENTS ENROLLED DECEMBER 5, 1924

19524 Camps, Antonio B., Mass. Inst. of Tech.
19525 Welch, Lewis M., Texas A. & M. College
19526 Williams, Lloyd T., Texas A. & M. College
19527 Engel, Kenneth E., Texas A. & M. College
19528 Ramsey, Louis W., Texas A. & M. College
19529 Clayton, Frank C. A., California Inst. of Technology
19530 Kiech, Clarence F., California Inst. of Technology
19531 DeVoe, Jay J., California Inst. of Tech.
19532 Byler, Albert E., California Inst. of Tech.
19533 Kroneberg, Alex A., California Institute of Technology
19534 Austin, Henry C., California Inst. of Tech.
19535 Phillips, Frank L., Univ. of Nebraska
19536 Kyle, John M., Jr., Stevens Inst. of Tech.
19537 Cullivan, Russell E., Northeastern Univ.
19538 Dreher, Carl E., Brown University
19539 Francis, Winthrop R., Mass. Inst. of Tech.
19540 Lee, George H., Armour Inst. of Tech.
19541 Yocum, Fred D., Armour Inst. of Tech.
19542 Kleist, Myron R., Armour Inst. of Tech.
19543 Goetz, Maurus T., Armour Inst. of Tech.
19544 Kenney, Clarence E., Armour Inst. of Tech.
19545 Althouse, Ernest E., Lehigh University
19546 Applegate, William M., Lehigh University
19547 Bigley, James W., Lehigh University
19548 Borenman, Walter H., Lehigh University
19549 Buenning, Carl A., Lehigh University
19550 Cetina, E. Renan, Lehigh University
19551 Corson, Osman M., Lehigh University
19552 Dyson, Robert H., Lehigh University
19553 Foster, Arthur, Lehigh University
19554 Gordon, Malcolm K., Jr., Lehigh Univ.
19555 Henke, Herman J., Lehigh University
19556 Kear, Frank G., Jr., Lehigh University
19557 Kennedy, Richard M., Lehigh University
19558 Maiese, Domenick, Lehigh University
19559 March, Robert C. R., Lehigh University
19560 Meyers, Edgar J., Lehigh University
19561 Mong, D. McM., Lehigh University
19562 Nagle, George S., Lehigh University
19563 Osborn, M. Howard, Lehigh University
19564 Rerig, Eugene L., Lehigh University
19565 Richman, Edwin, Lehigh University
19566 Scott, Wilson W., Jr., Lehigh University
19567 Shoup, Raymond A., Lehigh University
19568 Shuhart, J. Henry, Lehigh University
19569 Washington, William deH., Lehigh Univ.
19570 Wintermute, Gerald H., Lehigh University
19571 Homer, Charles C., Johns Hopkins Univ.
19572 Schmidt, Charles J., Univ. of Wisconsin
19573 Staylor, John C., Johns Hopkins Univ.
19574 Peck, J. Kenyon, Mass. Inst. of Tech.
19575 Shafer, David P., Johns Hopkins Univ.
19576 Stephenson, George W., Texas A. & M. Col.
19577 Hunt, Stanley B., University of Illinois
19578 Bourland, L. T., University of Illinois
19579 Haskell, Robert N., University of Maine
19580 Billings, Maurice P., University of Maine
19581 Leighton, Cecil V., University of Maine
19582 Gerrish, Harold L., University of Maine
19583 Allan, John C., University of Toronto
19584 Takaba, Sueich, University of Toronto
19585 Campbell, Wilfred J., Univ. of Toronto
19586 Griffith, Barrett C., University of Toronto
19587 MacQueen, Fred, University of Toronto
19588 Lloyd, Davis S., University of Toronto
19589 Thomson, William H., Univ. of Toronto
19590 Brewer, Glen E., Cornell University
19591 Coleman, James E., Cornell University
19592 Courtright, Alva V., Cornell University
19593 DeWitt, Charles V., Cornell University
19594 Fox, James, Cornell University
19595 Frey, William L., Cornell University
19596 Hill, Melvin L., Cornell University
19597 Huntsinger, Franklin J., Cornell University
19598 Mott-Smith, R. H., Cornell University
19599 Nevins, Irvin, Cornell University
19600 Samson, Hector, B., Cornell University
19601 Shafer, Arthur H., Cornell University
19602 Van Wynen, Kenneth G., Cornell Univ.
19603 Whitney, Alexander, Cornell University
19604 Wood, John P., Cornell University
19605 Zucker, Myron, Cornell University
19606 Schoenhaar, Leslie H., Johns Hopkins Univ.
19607 King, Barnwell R., Univ. of Maryland
19608 Farrar, Harry K., Calif. Inst. of Tech.
19609 Fisher, Elmer H., Calif. Inst. of Tech.
19610 Gockley, Roscoe, California Inst. of Tech.
19611 Gottier, Thomas, California Inst. of Tech.
19612 Howell, J. Roscoe, Calif. Inst. of Tech.
19613 Jaeger, Vernon P., Calif. Inst. of Tech.
19614 Knupp, Seerley G., Calif. Inst. of Tech.
19615 Schell, Frederick T., Calif. Inst. of Tech.
19616 Southwick, Thomas S., Calif. Inst. of Tech.
19617 Streit, Frank H., Calif. Inst. of Tech.
19618 Giovannoli, Robert, Univ. of Kentucky
19619 Gray, Clyde W., Univ. of Kentucky
19620 Orman, Charles L., Univ. of Kentucky
19621 Porter, R. C., University of Kentucky
19622 Trosper, Ralph S., Univ. of Kentucky
19623 Willis, James M., Univ. of Kentucky
19624 Gronhovd, Helmer, Univ. of North Dakota
19625 Hammelsmith, Jack, Univ. of N. Dakota
19626 Medalen, Olvin B., Univ. of North Dakota
19627 Peterson, James J., Univ. of N. Dakota
19628 Peterson, Merton D., Univ. of N. Dakota
19629 Russ, George H., Univ. of North Dakota
19630 Anderson, Lowell W., Univ. of Minnesota
19631 Ayshford, Loren C., Univ. of Minnesota
19632 Barron, J. H., Univ. of Minnesota
19633 Berghs, Charles J., Univ. of Minnesota
19634 Bergman, Hilder W., Univ. of Minnesota
19635 Beveridge, Robert A., Univ. of Minnesota
19636 Bullard, Henry M., Univ. of Minnesota
19637 Garman, Willard J., Univ. of Minnesota
19638 Christen, Ray L., Univ. of Minnesota
19639 Coon, Lawrence C., Univ. of Minnesota
19640 Dahl, Merle G., Univ. of Minnesota
19641 Deinema, George R., Univ. of Minnesota
19642 Deterling, Edward W., Univ. of Minnesota
19643 Dickerson, Clifton R., Univ. of Minnesota
19644 Dimmick, Merton A., Univ. of Minnesota
19645 Eller, Floyd E., Univ. of Minnesota
19646 Etem, Victor, Univ. of Minnesota
19647 Faulkner, L. Lester, Univ. of Minnesota
19648 Feldman, Carl B., Univ. of Minnesota
19649 Ferguson, Kenneth R., Univ. of Minnesota
19650 Fiene, Marcus, Univ. of Minnesota
19651 Forsmark, Emanuel, Univ. of Minnesota
19652 Galipeau, Leon M., Univ. of Minnesota
19653 Gemmell, Robert W., Univ. of Minnesota
19654 Gross, Leon A., Univ. of Minnesota
19655 Haedecke, Gus D., Univ. of Minnesota
19656 Hafstad, Lawrence R., Univ. of Minnesota
19657 Hargrave, W. A., Univ. of Minnesota
19658 Hart, Maurice W., Univ. of Minnesota
19659 Hilgedick, Win C., Univ. of Minnesota
19660 Hilliard, John K., Univ. of Minnesota
19661 Hummel, Carl A., Univ. of Minnesota
19662 Irons, George R., Univ. of Minnesota
19663 Jensen, Otto, Univ. of Minnesota
19664 Joesting, Frederick D., Univ. of Minnesota
19665 Johnson, Clarence A., Univ. of Minnesota
19666 Jones, Richard W., Univ. of Minnesota
19667 Lee, Albert A., Univ. of Minnesota
19668 LeVesconte, Lester B., Univ. of Minnesota
19669 Lostrom, Herbert W., Univ. of Minnesota
19670 Lynskey, J. Philip, Univ. of Minnesota
19671 Mackay, D. H., Univ. of Minnesota
19672 Meader, Glenn S., Univ. of Minnesota
19673 Nelson, Paul B., Univ. of Minnesota
19674 Nelson, Robert B., Univ. of Minnesota
19675 Orning, Harold, Univ. of Minnesota
19676 Osburn, Roy W., Univ. of Minnesota
19677 Quine, Milton W., Univ. of Minnesota
19678 Rhoades, Herbert E., Univ. of Minnesota
19679 Ronning, Norman, Univ. of Minnesota
19680 Salstrom, Paul S., Univ. of Minnesota
19681 Sandell, Paul W., Univ. of Minnesota
19682 Schroeder, Clarence A., Univ. of Minnesota
19683 Schweppe, Walter A., Univ. of Minnesota
19684 Sjoberg, Roy H., Univ. of Minnesota
19685 Slaggie, E. Leo, Univ. of Minnesota
19686 Thompson, Niles J., Univ. of Minnesota
19687 Tighe, James S., Univ. of Minnesota
19688 Walters, Robert P., Univ. of Minnesota
19689 Wentz, Edward C., Univ. of Minnesota
19690 Westigard, Glenn S., Univ. of Minnesota
19691 Williams, W. Rowe, Univ. of Minnesota
19692 Stutz, Louis R., Stevens Inst. of Tech.
19693 Parker, George A., Jr., Stevens Institute of Technology
19694 Rateike, George, Univ. of Wisconsin
19695 Chan, Hoh C., Mass. Inst. of Technology
19696 Knight, H. E. H., Mass. Inst. of Tech.
19697 Sharpe, James M., McGill University
19698 Worth, Arnold M., Northeastern Univ.
19699 Boardman, George R., Jr., University of Pittsburgh
19700 Boggs, George H., University of Pittsburgh
19701 Casey, Edward A., Univ. of Pittsburgh
19702 Dalzell, Clarence W., Univ. of Pittsburgh
19703 Dively, George S., Univ. of Pittsburgh
19704 Dively, William L., Univ. of Pittsburgh
19705 Hawbecker, Russell A., Univ. of Pittsburgh
19706 Kilgallen, Aloysius P., Univ. of Pittsburgh
19707 Lange, Julius E., Univ. of Pittsburgh
19708 Lister, David, Univ. of Pittsburgh
19709 Pesquera, Quirino, Univ. of Pittsburgh
19710 Templeton, D. Stewart, University of Pittsburgh
19711 Thompson, Howard A., Univ. of Pittsburgh
19712 Young, Hulbert, Jr., Johns Hopkins Univ.
19713 Kernahan, Ray, Washington State College
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19715 Bower, Maxwell, California Inst. of Tech.
19716 Capon, Alan E., California Univ. of Tech.
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19718 Gainder, Melvin E., Calif. Univ. of Tech.
19719 Gilliland, Ted R., Calif. Univ. of Tech.
19720 Hansen, Raymond J., Calif. Inst. of Tech.
19721 Hayward, Claude D., Calif. Inst. of Tech.
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19723 Lord, Harold W., California Inst. of Tech.

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19725 Morris, F. Hampton, Penn. State College
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19784 Merrill, Harold F., Oregon Agri. College
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19882 Goudey, Donald K., Yale University
19883 Shepard, Herman C., Yale University
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19897 Robinson, Leslie L., Ohio State University
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19899 Rose, Allen M., Ohio State University
19900 Klopfer, Lewis R., Ohio State University
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19928 Brundage, Howard F., School of Engineering of Milwaukee
19929 Chatt, Willard, F., School of Engineering of Milwaukee
19930 Harris, Edgar L., School of Engineering of Milwaukee
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19944 Howard, C. Wesley, Univ. of Washington
19945 Joyce, Robert W., Univ. of Washington
19946 Merrill, Elliott, Univ. of Washington
19947 Scott, Herbert J., Univ. of Washington
19948 Sopwith, Edward C., Univ. of Washington
19949 Fouchaux, Julien E., Lehigh University
19950 Hayes, D. Frank, Lehigh University
19951 Blackmon, Hendley N., George School of Technology
19952 Busby, Terrell A., Georgia School of Tech.
19953 Campbell, Curtis R., Georgia School of Technology
19954 Davis, N. Knowles, Georgia School of Tech.
19955 Tenzel, V., Georgia School of Technology
19956 Armstrong, Harrison R., Jr., Univ. of Idaho
19957 Beam, Richard C., University of Idaho
19958 Bouse, Robert C., University of Idaho
19959 Curtis, Homer T., Universty of Idaho
19960 Foskett, Laurence W., University of Idaho
19961 Gutton, Norvin J., University of Idaho
19962 Kilimann, William, University of Idaho
19963 Samms, Philip C., University of Idaho
19964 Schroeder, William, University of Idaho

19965 Shoults, David R., University of Idaho
19966 Soderberg, Arnold O., University of Idaho
19967 Soklnikoff, Ivan S., University of Idaho
19968 Robb, Charles, Drexel Institute
19969 Knull, Jacob R., University of Denver
19970 Marshall, J. Clarence, Univ. of Denver
19971 Thomson, James F. P., California Inst. of Technology
19972 Wilson, Keith M., California Inst. of Tech.
19973 Moses, Bernard S., Johns Hopkins Univ.
19974 Tuttle, Walter H., Lafayette College
19975 Stoddard, Kenneth B., Univ. of California
19976 Hileman, W. R., Purdue University
19977 Hufler, Joyse P., Purdue University
19978 Malsbary, James S., Purdue University
19979 Sevedge, Wallace A., Purdue University
19980 Swain, J. V., Purdue University
19981 Woods, Charles A., Purdue University
19982 Eller, Keith B., Ohio State University
19983 Ganz, Arthur W., Rhode Island State Col.
19984 Bridge, John F., Univ. of Toronto
19985 Bruce, Douglas, Univ. of Toronto
19986 Jackson, Thomas W., Univ. of Toronto
19987 Milne, Frederick J., Univ. of Toronto
19988 Papst, Hugh W., Univ. of Toronto
19989 Dybvig, Henry G., South Dakota State Col.
19990 Marak, Charles T., Univ. of Arkansas
19991 McCain, Hugh M., Univ. of Arkansas
19992 Purdy, Russell T., Univ. of Arkansas
19993 Walker, J. Barry, Univ. of Arkansas
19994 Whitaker, Gilbert R., Univ. of Arkansas
19995 Tylor, Harry L., Johns Hopkins University
19996 Houghton, Marshall G., Michigan Agricultural College
19997 Dausman, Orin D., Michigan Agricultural College
19998 Spangler, Robert L., Marquette University
19999 Dempsey, John V., Johns Hopkins Univ.
Total 476

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*Alexander Graham Bell, 1891-2.
Frank Julian Sprague, 1892-3.
*Edwin J. Houston, 1893-4-5.
*Louis Duncan, 1895-6-7.
*Francis Bacon Crocker, 1897-8.
A. E. Kennelly, 1898-1900.
Carl Hering, 1900-1.
*Charles P. Steinmetz, 1901-2.
Charles F. Scott, 1902-3.
Bion J. Arnold, 1903-4.
John W. Lieb, 1904-5.
*Schuyler Skaats Wheeler, 1905-6.
*Samuel Sheldon, 1906-7.
*Henry G. Stott, 1907-8.
Louis A. Ferguson, 1908-9.
Lewis B. Stillwell, 1909-10.
Dugald C. Jackson, 1910-11.
Gano Dunn, 1911-12.
Ralph D. Mershon, 1912-13.
C. O. Mailloux, 1913-14.
Paul M. Lincoln, 1914-15.
John J. Carty, 1915-16.
H. W. Buck, 1916-17.
E. W. Rice, Jr., 1917-18.
Comfort A. Adams, 1918-19.
Calvert Townley, 1919-20.
A. W. Berresford, 1920-21.
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(Term expires July 31, 1926)
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(Term expires July 31, 1927)
Gano Dunn, Chairman, F. A. Scheffler, W. R. Whitney.
(Term expires July 31, 1928)
C. C. Chesney, Robert A. Millikan, M. I. Pupin.
(Term expires July 31, 1929)
N. A. Carle, W. C. L. Eglin, John W. Lieb.
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(Term expires July 31, 1926)
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Testing Transformers.—Bulletin 1025, 6 pp. Describes a wide range of testing sets for laboratory and industrial uses. American Transformer Company, 176 Emmet Street, Newark, N. J.

Motor Starter.—Bulletin 106, 12 pp. Describes Monitor "Thermaload" starter for small alternating-current motors. Monitor Controller Company, Baltimore, Md.

Motors.—Bulletin 1652, 12pp. Describes industrial and marine applications of Diehl electric motors. Diehl Manufacturing Company, Elizabeth, N. J.

Meter Repair Parts.—Bulletin, Parts List No. 9. 24 pp. Comprises price list of repair parts for the Sangamo Type H Watthour Meters. Sangamo Electric Company, Springfield, Ill.

Motor Starters.—Bulletin 64, 4 pp. Describes Ward Leonard motor starters and controllers for alternating current. Ward Leonard Electric Company, Mount Vernon, N. Y.

Combustion Recorders.—Catalog 32, 16 pp., entitled "Measuring CO_2 Electrically." Describes graphic recorders and other instruments for indicating combustion conditions. The Brown Instrument Company, Philadelphia, Pa.

Diesel Engines.—Bulletin 807, 8pp., "The Diesel Engine in Medium Powered Central Stations." This bulletin is a reprint of a paper read before the A. S. M. E. at St. Louis. Fulton Iron Works Co., St. Louis, Mo.

Surface Air Cooler.—Bulletin 45609, 12pp. Describes general construction, principles of operation and exclusive features of the G-E surface air cooler. A partial list of installations of this make of cooler is included. General Electric Company, Schenectady, N. Y.

Circuit Breakers.—Bulletin 530, 24 pp. Describes the standard line of Roller-Smith circuit breakers, including a new double pole "interlocked trip breaker," the particular feature of which is that the two poles are closed independently and successively. Another new device is the "shock proof" circuit breaker for installations in which there are apt to be conditions of excessive mechanical vibration. Roller-Smith Company, 12 Park Place, New York.

Radio Frequency Transformers.—Bulletin. Describes newly marketed "airplane" type frequency transformers, which have been adopted as standard by the Signal Corps, U. S. A. for airplane use. Such types were installed in government airplanes and perfect reception maintained despite the disturbance set up by the Liberty engines and the air rush of the propellers. The transformers are sold in sets at a reasonable cost and are recommended by the manufacturer in radio receiver construction where great range and precision are desired. Sangamo Electric Company, Springfield, Ill.

Transformer Breathers.—Bulletin Ta 172, 4pp. Describes Ferranti oil-sealed calcium chloride breathers. This type of device embodies a charge of calcium chloride which is only in direct contact with air passing through the breather to or from the transformer, and allows automatic discharge of free water deposited within the breather. The advantage of the present type over previous designs is that the depreciation of the salt is not continuous and thus the need of replenishing is not so frequent. Ferranti, Ltd., Hollinwood, Lancashire, England.

NOTES OF THE INDUSTRY

Elevator Supplies Company, Hoboken, N. J., manufacturers of elevator signals, accessories and dumb waiters, etc., have opened an office at 119 Spring Street, Atlanta, Ga. W. A. Crowe, who has been for many years in charge of the Philadelphia office, will take charge of the Atlanta territory, and Harry Weldon will succeed Mr. Crowe in Philadelphia.

Locke Insulator Corporation Supplants Agents by District Offices.—Beginning January 1, the sales department in charge of B. A. Plimpton, general sales manager, and the engineering department, K. S. Hawley, chief engineer, will be located in the Maryland Trust Building, Baltimore, Md., where the executive offices are located. Newly established company district offices to take the place of former sales agencies, are at Chicago, Philadelphia, and Victor, N. Y.

Record Year's Sales for Western Electric Company.—Sales of one million dollars for every working day of the year will be the record total of the Western Electric Company during 1924. The new record, the highest in the fifty-five years of the Company's history, represents in large measure a period of intensive effort by the Bell Telephone System to catch up with the growing demand for telephones. The sales of the company in 1923 were $255,177,000; in 1922, $210,941,000.

Large Order for Westinghouse.—An order amounting to $1,250,000 for railway equipment for the Brooklyn City Railroad Company has been received by the Westinghouse Electric & Manufacturing Company. The contract includes a total of 1340 thirty-five horse-power motors. This equipment will be installed on 335 new light weight, double truck, four-motor street cars, which will have a seating capacity of fifty persons and will be operated by one man during non-rush hours.

Norma-Hoffmann Bearings Corporation Occupies New Factory. The factory and general offices of the Norma-Hoffmann Bearings Corporation have been moved from Long Island City, N. Y., to Stamford, Conn., where a modern plant has just been completed on a tract of 17 acres adjoining the main line of the N. Y., N. H. & H. R. R. One feature of this factory, which is given over entirely to the manufacture of Norma Precision Ball Bearings and Hoffmann Precision Roller Bearings, is the use of ball and roller bearings in motors, shafting and other power equipment, to an extent probably not elsewhere found.

The Packard Electric Company, Warren, Ohio, have completed the design of a full new line of steel cases for distribution transformers. The use of iron cases has been discontinued and all shipments are being made in the new cases. In addition to a complete line of distribution transformers, the company manufactures power transformers up to a capacity of 10,000 kv.-a. and a complete line of weatherproof metering transformers both in the form of individual units, and also with both units contained in the same oil-filled case. The new steel cases will also be used in connection with Packard A. W. Regulators.

Holslag Welding Patents Again Upheld.—The Circuit Court of Appeals of the District of Columbia rendered a decision on December 1, 1924, sustaining the concurrent decisions of all tribunals of the United States Patent Office in awarding to Claude J. Holslag priority of invention over Charles B. Waters on the subject of alternating-current arc welding transformers. These inventions are described in Holslag Patents 1,305, 360-1-2-3 which were involved in said interference, the broad as well as the specific subject matter being thoroughly considered by the various tribunals during the prolonged litigation. No unfair advantage of the position in which the Circuit Court of Appeals places them, will be taken, according to the Electric Arc Cutting and Welding Company, Newark, N. J., owners of these patents, as they have, since the decision was handed down, licensed one company that has been making infringing apparatus and a few more licenses will be granted to reputable companies, as it is believed by the owners of the patents that by so doing the best interests and progress of arc welding will be served.